[COMMITTEE PRINT]

SOVIET SPACE PROGRAMS, 1971–75

OVERVIEW, FACILITIES AND HARDWARE, MANNED AND UNMANNED FLIGHT PROGRAMS, BIOASTRONAUTICS, CIVIL AND MILITARY APPLICATIONS, PROJECTIONS OF FUTURE PLANS

STAFF REPORT

PREPARED FOR THE USE OF THE

COMMITTEE ON
AERONAUTICAL AND SPACE SCIENCES
UNITED STATES SENATE

BY THE

SCIENCE POLICY RESEARCH DIVISION,
CONGRESSIONAL RESEARCH SERVICE,
THE LIBRARY OF CONGRESS

VOLUME I

August 30, 1976.—Ordered to be printed

Printed for the use of the Committee on Aeronautical and Space Sciences

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S. Con. Res. 113

Agreed to AUGUST 30, 1976.

Resolved by the Senate (the House of Representatives concurring), That there be printed for the use of the Senate Committee on Aeronautical and Space Sciences one thousand five hundred additional copies each of volumes 1 and 2 of its committee print entitled "Soviet Space Programs, 1971–1975", Ninety-fourth Congress, second session, prepared by the Congressional Research Service with the cooperation of the Law Library, Library of Congress.

Attest:

FRANCES R. VALEO,
Secretary.

LETTER OF TRANSMITTAL

THE LIBRARY OF CONGRESS,
CONGRESSIONAL RESEARCH SERVICE,
Washington, D.C., January 29, 1976.

Hon. FRANK E. MOSS,
Chairman, Committee on Aeronautical and Space Sciences,
U.S. Senate, Washington, D.C.

DEAR SENATOR MOSS: Pursuant to your letter of request, the Congressional Research Service with the cooperation of the Law Library has undertaken a study of the Soviet space program for the years 1971–75. The study has been divided into two volumes, of which this is the first.

The purpose of the study is to bring up to date previous reports prepared by the Library of Congress for your committee, published in 1962, 1966, and 1971.

The first volume has been completed and is herewith submitted.

This volume has sought to review Soviet space resources, facilities and hardware, past and on-going programs of flights, research and applications, and projections of future plans.

It should be emphasized that the report is based exclusively upon unclassified, open sources, both Soviet announcements and independent checks on such data derived from U.S. observational equipment whose findings are published in this country, and from corresponding British data. A comparison of information in this report with that in classified sources has not been made.

Dr. Charles S. Sheldon II, Chief of the Science Policy Research Division and Senior Specialist in Space and Transportation Technology, Congressional Research Service, has been coordinator of the project. Also, he has been responsible for writing the summary, Chapters 1, 2, 6 and 7, plus preparing the appendices.

Ms. Marcia S. Smith, Analyst in Science and Technology, Congressional Research Service, has been responsible for writing Chapter 3.

Mr. Christopher H. Dodge, Analyst in Life Sciences, Congressional Research Service, has been responsible for writing Chapter 4.

Ms. Lani Hummel Raleigh, Analyst in Physical Sciences, Congressional Research Service, has been responsible for writing Chapter 5.

Ms. Vikki A. Zegel, Analyst in Life Sciences, Congressional Research Service, has been responsible for writing the Chapter 3 Annex.

Mr. J. Glen Moore, Analyst in Science and Technology, Congressional Research Service, has been responsible for writing the Chapter 7 Annex.

Mr. Geoffrey E. Perry, leader of the Kettering Group based in the United Kingdom, has been responsible for writing the Chapter 5 Annex and the two Chapter 6 Annexes.

The study has been reviewed by appropriate individuals in more than one institution of Government in the interest of accuracy and security, although the final responsibility rests with the authors and the Congressional Research Service. Thanks are also extended to the following additional consultants and reviewers of the entire volume: Mr. Geoffrey E. Perry, Mr. David R. Woods, Mr. Charles P. Vick, and Mr. Maarten Houtman.

Sincerely yours,

NORMAN BECKMAN,
Acting Director.

Enclosure.

LETTER OF TRANSMITTAL

United States Senate,
Committee on Aeronautical and Space Sciences,
Washington, D.C., June 11, 1976.

Hon. Frank E. Moss,
Chairman, Committee on Aeronautical and Space Sciences,
Washington, D.C.

Dear Mr. Chairman: Transmitted herewith is a report, Soviet Space Programs, 1971–1975, in two volumes. The report was prepared for the use of the Committee by the Congressional Research Service, with the cooperation of the Law Library, Library of Congress. This report is a follow-on to similar reports published at intervals since 1962. It is, as are its predecessors, a comprehensive and detailed study of the Soviet space program.

Volume I provides an overview of the Soviet space program, its facilities and hardware, the manned and unmanned Soviet space missions, Soviet bioastronautics, Soviet civilian and military applications, and projects future Soviet space plans. Volume II examines the goals and purposes of the Soviet space program, the organization of space activities in the Soviet Union, allocation of resources to Soviet space activities and Soviet attitudes towards international space cooperation and space law.

The report was prepared under the direction of Dr. Charles S. Sheldon, II of the Congressional Research Service, Library of Congress. Dr. Sheldon, one of the free world's foremost authorities on Soviet space activities, is also the major contributor to the study. Other parts of the study were prepared by other experts in the Library of Congress, and Geoffrey E. Perry, consultant from the United Kingdom.

Mr. Fred Doering of the Government Printing Office prepared the report for printing.

In every respect this report is a remarkable accomplishment. It represents scholarship at the highest level but was done at minimum cost.

I believe that this study of Soviet space programs has resulted in an important report and will be most useful to the Committee and to other members of the Congress.

Respectfully,

Gilbert W. Keyes,
Staff Director.

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SUMMARY

By Charles S. Sheldon II*

I. Overview. Supporting Facilities and Launch Vehicles of the Soviet Space Program

A. OVERALL TREND

Statistics on space activities are only approximate and are subject to revision, but enough data are available to afford a reasonably good overview of rates of relative progress among nations.

1. Gross Statistics

Although the U.S. launch pace has declined since 1966, the Soviet record shows no similar drop, and now runs about three times as high as the current U.S. level. While the U.S. record of failures in flight is fairly well known, the Soviet Union continues to hide most of its failures, and these can only be estimated as probably proportional to the number of successes in the same ratio as applies to the U.S. space record.

2. Breakdown by Categories

Despite Soviet and U.S. secrecy in hiding the missions of military space flights which overall make up a majority of launches, in both cases it is possible from open sources to deduce these missions. The largest single component in both programs are the flights which have a recoverable payload from low Earth orbit, presumably flown for observation purposes. Examination of 27 program elements shows that both the U.S. and Soviet programs are broadly based, seeking multiple goals, with the primary difference being the Soviet inclusion of fractional orbit bombardment satellites (FOBS) and satellite inspector/destructor flights. These flights have no U.S. counterparts and on the Soviet side have ceased after 1971.

3. Comparative Weights of Payload

In the absence of published data, only estimates can be made, and the launch capacity of the rockets used have been normalized to nominal low Earth orbit equivalents. These show the Soviet Union cumulatively has launched about 50 percent more tonnage than the United States, and is currently running about four-fold the U.S. level, now that the Saturn V has been withdrawn from use.

B. LAUNCH SITES IN THE SOVIET UNION

1. Tyuratam

This site, in Kazakhstan, is the Cape Canaveral of the Soviet Union, launching many research and development (R & D) flights, some ob-

*Dr. Sheldon is chief of the Science Policy Research Division, Congressional Research Service, The Library of Congress.

servation flights, all manned, lunar, and planetary flights. It is officially called the Baykonur Cosmodrome, but it is 370 kilometers southwest of Baykonur, adjacent to the new rocket city of Leninsk.

2. Plesetsk

This is the Vandenberg Air Force Base of the Soviet Union, located north of Moscow toward Arkhangelsk. It is used mostly for military operational flights, most civil applications flights, and for extreme latitude scientific flights. It has never been named or pinpointed by the Russians.

3. Kapustin Yar

This site on the Volga River near the Caspian Sea is equivalent to White Sands, New Mexico and Wallops Island, Virginia. It is used to launch vertical probes and small satellites for civilian and military purposes, as well as conducting missile tests. The Russians now identify it as the Volgograd Station.

C. SOVIET LAUNCH VEHICLES

1. The Standard Launch Vehicle Series ("*A*")

This adaptation of the 1957 SS–6 Sapwood ICBM (intercontinental ballistic missile) is still the mainstay of the Soviet program, with a first stage thrust of about 500 metric tons. It was used for Sputnik 1 and still is used for the Soyuz and many other flights today. It has been used more times than any other orbital launch vehicle in the world. With improved upper stages it will put up to 7.5 metric tons of payload in orbit. It is launched at Tyuratam and Plesetsk.

2. The Small Utility Launch Vehicle ("*B*")

This adaptation of the SS–4 Sandal MRBM (medium range ballistic missile) is used for the smallest direct-injection Kosmos flights probably with payloads ranging up to about 400 kilograms. It has been launched to orbit from Plesetsk and Kapustin Yar (first in 1962).

3. The Flexible Intermediate Vehicle ("*C*")

This adaptation of the SS–5 Skean IRBM (intermediate range ballistic missile) may be able to put as much as one metric ton into low orbit. With a restartable upper stage, it is able to put payloads into circular orbits at various altitudes at least up to 1,500 kilometers. It is launched from Plesetsk and Kapustin Yar, and used to be launched from Tyuratam, starting in 1964.

4. The Non-Military Large Launch Vehicle ("*D*")

First used for the Proton scientific payloads, it is now used for deep space flights to the Moon and planets, for 24-hour synchronous flights, and for Salyut space stations. It can put about 20 metric tons into Earth orbit, or send up to about 5 metric tons toward a near planet at a favorable window. It is launched from Tyuratam, beginning in 1965.

5. The Military Combat Space Launch Vehicle ("*F*")

This adaptation of the SS–9 Scarp is used from Tyuratam to put up ocean surveillance radar flights, and earlier was used to loft both FOBS (fractional orbit bombardment system) and inspector/destructor flights. It has never been announced as in use for a definable scientific or civilian mission. Flights to orbit began in 1966.

6. The Very Heavy Launch Vehicle ("G")

Presumably this was first launched in 1969, but through 1975, it had not made a successful flight. It may be designed to put about 135 or more metric tons into Earth orbit, or to send over 60 metric tons toward the Moon after Earth orbit rendezvous with other elements. Estimates of first stage thrust range as high as 6,300 metric tons.

D. TRACKING AND OTHER GROUND SUPPORT

1. Communications Needs

Tracking and communications with spacecraft are necessary to their successful use. The early Soviet support in this regard was limited and has had to be improved.

2. Earth Orbital Tracking in the U.S.S.R.

Soviet tracking facilities have been identified in part in connection with the recent Apollo-Soyuz Test Project, and some very elaborate missile and space defense tracking systems are also known to exist. The vast geographic extent of the U.S.S.R. provides a fairly adequate setting for such work.

3. Foreign Tracking Stations

There is a scattering of relatively modest tracking stations in Africa, Cuba, and probably at Kerguelen and in Antarctica, but nothing corresponding to the big stations used by the United States at some overseas locations.

4. Sea-Based Support

In the absence of good land-based overseas tracking stations, the Russians have put into service some fairly impressive large tracking ships both for Earth orbital support and for deep space mission support.

5. Deep Space Tracking

While deep space operations are aided by tracking ships, and there may be facilities in the Far East, the main deep space station is at Yevpatoriya in the Crimea, also the main flight operations center for Earth orbital flight.

6. Space Operations and Data Processing Centers

These were relatively simple at first, but over the years, better computer support and graphic displays have been introduced at the launch sites, at Yevpatoriya, and now at another manned operations center at Kaliningrad near Moscow.

7. Space Research Centers

Limited information is available about such space research centers. Two well-known ones are the Leningrad Gas Dynamics Laboratory and the Moscow Space Research Institute.

8. Manufacturing and Assembly Centers for Spacecraft and Rockets

Probably much construction is carried out in conjunction with aircraft plants, with use of rail transport to deliver modules to the assembly buildings at the launch sites for further testing.

9. Test and Training Centers for Space

Environmental chambers and other test equipment are used increasingly, often with the actual flight matched on Earth by an analog exposed to as close to the same environment as can be achieved. The principal training center for manned flight is at Zvezdnyy Gorodok in the Moscow suburbs.

II. Program Details of Unmanned Flights

A. EARLY YEARS

Interest in the Soviet program for space dates back at least to the last century when Konstantin Tsiolkovskiy, now the patron saint of the space program, began publishing his ideas in this regard. Soviet space plans were announced for the International Geophysical Year in 1955, a day after the announcement of Project Vanguard, but these turned out to be about two orders of magnitude more ambitious.

The first Sputnik (October 4, 1957) and Luna flights had great political impact upon the world position of the Soviet Union. Preparations for manned flights and for flights to the planets followed in quick succession. During the mid-1960's, the Soviet space program began to proliferate in many directions including work aimed at practical applications of a civilian and military character.

B. THE KOSMOS PROGRAM

From 1962 on, most Soviet flights were simply named Kosmos and given a number. This sweeping label covered a great variety of scientific, manned precursor, and military end uses, and also was used to disguise certain failures which attained Earth orbit, but did not accomplish their probable full purpose. Even so, through study of repetitive patterns in orbits, the kind of debris associated with flights, and the timing of these flights, it has been possible to group most of these individual payloads according to their mission purpose.

1. Kosmos Scientific Missions

The early B–1 launched Kosmos flights were scientific, roughly equivalent to the National Aeronautics and Space Administration's (NASA) Explorer series. These came from Kapustin Yar, and then occasionally from Plesetsk. When they carried experiments from other countries of the Soviet Bloc as well, they were generally named Interkosmos.

For the last few years, virtually all Kosmos and Interkosmos scientific flights have been launched by the larger C–1 class vehicle from Plesetsk and Kapustin Yar.

Some of the military observation flights launched by the A–1 or A–2 vehicles have carried supplemental experiments related to science, and over a period of time references to the findings have appeared in the literature, but the main mission is not mentioned.

2. Kosmos Precursor Flights

About 23 flights related to the manned program have carried Kosmos names. At least 9 flights with the Kosmos label were direct precursors of the Meteor weather satellites. A miscellany of other precursor flights, also received the Kosmos label.

3. Flight Mission Failures Disguised as Kosmos.

At least 11 mission failures received Kosmos names.

C. OTHER RECENT SCIENTIFIC FLIGHTS

1. The Prognoz Program

Four long-duration flights related to measuring solar weather phenomena and their interactions with Earth have been launched under the label Prognoz.

2. French Payloads Carried by Soviet Launch Vehicles

Oreol (Aureole) 1 and 2 have been French spacecraft used for auroral studies as a follow-on both to Soviet Bloc auroral studies and to French-Soviet conjugal point studies between Kerguelen and the Soviet arctic under the code name Arkad.

MAS(SRET)–1 and 2 have been small French engineering test satellites carried along on the same flights as Soviet Molniya communications flights. Individual French experiments have been carried on other Soviet flights, including Prognoz, a biological Kosmos, and on lunar and planetary flights.

3. Indian and Swedish Payloads Carried by Soviet Launch Vehicles

In 1975, the Indian payload Ariabat (Aryabhata) was launched from Kapustin Yar on a C–1 vehicle. A much more ambitious payload to do Earth resources work is expected to be launched in 1977 or 1978.

With little fanfare, a Swedish cooperative program also has begun, although the first payload in 1975 with a Swedish experiment failed to attain orbit. More are to follow.

4. Soviet Vertical Rocket Probes

Most major sounding rocket launchings are conducted from Kapustin Yar. Both geophysical rockets and animal flights have been carried out. The international part of the program applies the name Vertikal to the flights.

D. THE SECOND GENERATION OF PLANETARY FLIGHTS

Most planetary windows to Mars and Venus have been used since 1960, with the exception of the time in the case of each planet that the launch vehicle was being upgraded from the A–2–e to the D–1–e, plus the 1975 Mars opportunity which was skipped because of the high energy requirements.

1. The Mars Attempts of 1971 and 1973

The move up to the D–1–e launch vehicle permitted Mars 2 and 3 to include both orbiter and lander craft within each 4,650-kilogram payload. The orbiters put secondary emphasis on picture-taking, but gathered a wide range of synoptic data. One lander did not make a soft landing; the other began a television transmission from the surface which was abruptly terminated before a complete picture was received. Because of higher energy requirements which cut the weight of payload available, tasks were further divided on the second occasion (1973). Mars 4 returned pictures but did not achieve orbit; Mars 5

did both. Mars 6 returned direct readings of the atmosphere but did not send signals from the surface; Mars 7 missed its landing, and flew by the planet. In summary, the flights fell well short of their goals, yet collectively returned valuable data.

2. The Venus Attempts of 1975

The use of the D–1–e launch vehicle permitted both Venera 9 and 10 to carry orbiters and landers, and each pair worked well. The landers repeated previous direct readings of the atmosphere and sent back surface pictures which showed rock formations, sunlight and shadows, and a view to the horizon. The orbiters as of this writing are probably still functioning, but only limited findings have been reported to date.

E. THE THIRD GENERATION OF LUNAR FLIGHTS

Starting in 1969, Soviet unmanned lunar flights graduated to use of the D–1–e, probably able to carry as much as 5,800 kilograms to the vicinity of the Moon. Luna 15 and two Earth-orbital Kosmos represented early trials which fell short of their objectives. (Luna 15 crashed on the Moon during the Apollo 11 mision.)

1. Luna 16, 18, 20, and 23

These four flights were all aimed at returning samples of lunar soil to Earth. Luna 16 and Luna 20 were both successful in making soft landings, using a television inspection system, then drilling for core samples which were loaded into a return vehicle which flew directly to Kazakhstan. The amounts returned were about 100 grams each, modest but enough for valuable analysis in several countries. Luna 18 landed in rough terrain (lurain) and did not survive. Luna 23 damaged its drill during the landing so was abandoned within three days.

2. Luna 17 and 21

Both spacecraft made soft landings to discharge on the surface remotely controlled roving scientific laboratories. Lunokhod 1 operated for about 10 months, traveling over 10 kilometers, returning over 20,000 television pictures, plus mechanical and chemical tests of the soil, and doing topographic studies and some astronomy. Lunokhod 2 operated over 3 months, traveling about 37 kilometers, and returning over 80,000 television pictures. It also made soil tests, topographical studies, and astronomical measurements.

3. Luna 19 and 22

Both spacecraft were placed in lunar orbit to do both high resolution and wider area photographic survey work, plus gathering synoptic data on orbital conditions. Each operated for something over a year. There were studies of the composition of surface rocks, circumlunar plasmas, solar radiation, Jupiter radio emissions, and lunar mascons.

III. Program Details of Man-Related Flights

A. EARLY YEARS

The Soviet program of manned flights was preceded by many vertical probes from Kapustin Yar carrying dogs and other animals to altitudes above the sensible atmosphere. Sputnik 2 carried the dog Layka to orbit.

A succession of precursor craft called Korabl Sputniks made Earth orbital flights including the first successful recovery on Earth with two dogs as passengers.

The flight of Yuriy Gagarin in Vostok 1 on April 12, 1961 created almost as much sensation in the world as did the flight of Sputnik 1 less than four years earlier. By 1963 there had been six manned flights, two pairs occurring at overlapping times, with the last flight occupied by a woman, Valentina Tereshkova.

The Voskhod follow-on flights included the first three-man crew and the first EVA (extra-vehicular activity).

B. THE SOYUZ PROGRAM

The attempted recovery of Soyuz 1 in 1967 resulted in the first flight death of a human being, although three American astronauts had been killed in a static test at Cape Canaveral three months earlier. The Soviet program back-tracked to more automated tests including the successful conduct of two sets of dockings within the Kosmos program.

By 1969, a manned docking was accomplished, and two crew members transferred by EVA from Soyuz 5 to Soyuz 4 to return to Earth. A complicated group flight of three manned ships that fall did not include a successful docking. Soyuz 9 in 1970 set a duration record of 18 days.

1. Soyuz Ferry Flights to Salyut Space Stations

In 1971, Soyuz 10 docked with a Salyut 1 station for a combined weight of over 25 metric tons. However, the station was not occupied. Shortly, three more men went up in Soyuz 11 to enter the station, with a total flight time of almost 24 days. A large variety of geophysical, astronomical, medical, and ship systems tests were conducted. Tragically, just before reentry, a pressure equalization valve stuck open, and when the ship had landed automatically, the men were found to be dead. This was a major setback to the Soviet schedule, and required more unmanned tests.

A Salyut 2 station was launched in 1973, but it failed within a matter of days, and was not visited by a Soyuz. Kosmos 557 that same spring was also a Salyut station and it failed even before the Salyut name could be applied. Soyuz 12 was sent to orbit in a two-man flight in 1973 as a check on improved systems for the Soyuz ferry version, returning to Earth in two days. With no Salyut station available, the year was closed out with an independent flight of Soyuz 13 doing the kind of astronomical work (but on a more limited scale) which was done with the Salyut station.

In 1974, Salyut 3 was put into a low orbit, with much the same characteristics as the aborted Salyut 2. It was judged to be largely a military observation flight, capable of operating either manned or unmanned. An all-military crew in Soyuz 14 went up for about 15 days and occupied the station. A similar crew in Soyuz 15 followed, but made poor approaches in rendezvous, so came down again in two days. Salyut 3 continued to operate in automatic mode to complete six months in orbit, during the course of which a data capsule was returned to Earth by remote control.

Salyut 4, with characteristics similar to Kosmos 557, was sent to a higher orbit late in 1974. During 1975, it was visited during a 30 day

flight by the crew of Soyuz 17, and then during a 63 day flight by the crew of Soyuz 18. Primary emphasis was put on astronomical work, although there was also study of Earth resources, medical problems, and ship systems. Late in the year Soyuz 20 made an unmanned flight to Salyut 4, and remained docked to it in a long-duration test as the year ended. Between the flights of Soyuz 17 and 18, another Soyuz was launched on April 5, 1975, which ran into difficulties during the launch phase, and an automatic abort put the crew down about 1,600 kilometers away from the launch site 20 minutes later. They were rescued.

2. The Apollo-Soyuz Test Project

As a result of U.S.-Soviet negotiations, agreement was reached to conduct a joint flight which would include the use of a new universal or androgynous docking system, together with the conduct of other experiments. On the Russian side, there were several unmanned precursor flights under the Kosmos label, and then Soyuz 16 in December 1974 was a complete analog for the flight to come, even to the test of a docking ring which it carried to orbit and then docked to several times.

On July 15, 1975, the joint flights occurred on time. Soyuz 19 was followed to orbit 7.5 hours later by an Apollo, and the two crews were united after Apollo conducted the active rendezvous and docking. Not only did the flight require development of the new docking system, but for the first time detailed engineering exchanges of information on hardware and procedures. The crews and their back-ups had to learn each other's languages. There were repeated trips between Houston and Zvezdnyy Gorodok, and eventually visits to both launch sites. For the first time the Soviet launch and recovery were shown live on worldwide television. For the most part, the flights went according to plan.

C. THE ZOND PROGRAM OF MANNED CIRCUMLUNAR PRECURSORS

Although Western observers had expected the Russians to be the first to send men around the Moon, a variety of delays and troubles beset this part of their program. Zond 4 through Zond 8 made unmanned flights testing various aspects of the operation which was to carry men as soon as the systems were man-rated. All those planned to pass near the Moon and return to Earth did so and were recovered. Most return approaches were over Antarctica toward the Indian Ocean. Zond 5 landed in that ocean. Zond 6 and 7 made a skip reentry over that ocean and flew on to Kazakhstan, thereby cutting the G load. Zond 8 approached Earth from the north, and landed in the Indian Ocean. But time and events had obsoleted the program, and no further developments have been noted since 1970.

D. THE SOVIET MANNED LUNAR LANDING PROGRAM

For a long time the Russians were sufficiently confident they would be the first to land men on the Moon that they made a number of predictions to this effect. Apollo eventually ended that hope. But if Apollo 11 had failed and lost the crew, and if the several Soviet required elements of technical systems for manned lunar landing operations had been more successful, they might have pursued their work

to be first. There is not much doubt that one by one they were developing the components needed for such lunar operations, and were learning the techniques of rendezvous, assembly, landing, and Earth return from lunar distances. The program was set aside for the present shortly after the first G–1–e vehicle failed in launch, and the Apollo 11 flight was successfully completed.

E. UNMANNED BIOLOGICAL FLIGHTS

Five payloads have been dedicated to Soviet biological experiments starting with Kosmos 110 in 1966, and continued with Kosmos 605, 690, 782, and Soyuz 20. These have carried a variety of animals, insects, plant life, and microorganisms. Kosmos 782 in the fall of 1975 has carried additionally experiments of the United States, France, Czechoslovakia and Romania.

IV. The Soviet Space Life Sciences

The Soviet space life sciences effort is the most comprehensive in the world, and information about this effort is surprisingly available to scientists in other countries. Subtle differences exist between the U.S. and Soviet approaches.

A. COSMONAUT SELECTION AND TRAINING

The cosmonaut selection and training process is evolving from a program of rigorous physical conditioning to one that is more specialized and task-oriented. More accurate quantitative methods are being developed to predict cosmonaut behavior and performance. More elaborate new training facilities and spaceship analogs have been constructed. The program encompasses preparation for orbital, lunar, and even interplanetary flight.

B. SPACE MEDICINE

The technology of medical monitoring, diagnosis, and treatment of disorders arising during progressively longer spaceflights has been significantly improved. Equipment has been developed to counteract the undesirable effects of spaceflight, mainly weightlessness. The foods available have been expanded and upgraded.

C. LIFE SUPPORT SYSTEMS AND TECHNOLOGY

While the basic Soviet life support systems remain the same, many modifications and improvements have been made in these systems, including better recycling of water and air. The ultimate goal is an almost totally closed ecological system able to perform reliably for months or years. Already ground tests of closed ecological systems have been operated up to one year, with lower plants, higher plants, and men.

D. GRAVITATIONAL BIOLOGY AND MEDICINE

These studies have received considerable attention, particularly in combination with other spaceflight factors. These include high gravity,

weightlessness, and rotatory accelerations to determine effects and human tolerances, and steps to overcome problems through physical conditioning and drugs.

E. SPACE RADIATION

Experiments in radiobiology are extensive, including study of preventive measures through use of drugs, shielding devices, and force fields. These studies extend to the conditions to be found on manned interplanetary flights.

F. GAS ATMOSPHERES AND PRESSURES

The Russians are making considerable study of the effects on the crews of different gases and atmospheres in life support systems. They are also studying the effects of altered atmospheric pressures, particularly sudden decompression phenomena, to learn limits of human tolerance and the prevention and treatment of related disorders. In general, they still favor spacecraft atmospheres as close to Earth's as possible. They are working on management of toxic substances that may be found in atmospheres.

G. SPACE BIOLOGY AND EXOBIOLOGY

Their unmanned biological satellites in recent years have grown in technological quality in their automated management and handling of large numbers of animals and plants in order to meet their metabolic requirements. They are studying with suitable parallel controls the effects separately and synoptically of weightlessness, radiation, and rotatory accelerations on their experimental subjects.

Study of exobiology includes the possible life forms that might exist on other planets, the detection of extraterrestrial life, and the search for intelligent life elsewhere in the universe.

H. CONCLUSION

Every sign points toward a continued commitment to manned flight even to the planets and beyond. The successes in the life sciences are already reflected in the operations of their orbiting stations. The space life sciences seem assured of continuing support at a high level.

V. Soviet Application of Space to the Economy

A. COMMUNICATIONS SATELLITES

1. Molniya Satellites

The principal part of the Soviet communications satellite program has revolved around repetitive use of the Molniya classes of payloads, put up by the A–2–e vehicle into an eccentric orbit ranging from around 500 kilometers in the southern hemisphere to about 40,000 kilometers in the northern hemisphere, and inclined at about 63 degrees to the Equator. Three satellites of the Molniya 1, 2, and 3 class variants are in the same plane in four groups 90 degrees apart for a total of 12 active at any one time, to meet military, international, and domestic television and civilian message traffic requirements. These satellites

connect with about 60 Earth terminals of the Orbita system. The use of the Molniya inclined, eccentric orbit has made it possible to put up heavier payloads of greater power to cut ground terminal costs, and to give good service to northern latitudes.

2. Statsionar Satellites

Starting in 1974, several years later than expected, the Russians have begun experimental flights to equatorial 24-hour synchronous orbits, fixed relative to a point on the surface of the Earth, by using the larger D–1–e launch vehicle. Late in 1975, the first Statsionar of 10 projected for the next five years was placed in orbit and given the new name Raduga.

3. International Cooperation

The Russians have moved at a deliberate pace to set up their own Intersputnik Soviet Bloc cooperative communications system in competition with the Intelsat consortium used by most of the rest of the world. However, they also have an Earth terminal near Lvov to link into the Intelsat system. The Washington-Moscow "hot line" uses both American satellites and Soviet Molniya satellites to link the two capitals.

4. Direct Broadcast

For the future, the Russians may overcome their own objections to direct broadcast satellites which could penetrate their censorship, and may create their own direct broadcast system. But their ambivalence shows in their proposal to permit action against program material offensive to the receiving nation through jamming or even satellite destruction.

B. METEOROLOGICAL SATELLITES

1. Meteor Satellites

Several years of expanding experimental service was carried on before the Meteor system was declared operational, and by the end of 1975, 24 satellites of that name had been placed in orbit. They are three-axis stabilized, and are launched by the A–1 vehicle. They carry television cameras with a resolution of about 1,200 meters, with two cameras each covering a slightly overlapping path about 1,000 kilometers wide. A separate infrared (IR) sensor system returns night pictures to supplement the day pictures. More recent flights have added APT (automatic picture transmission) for realtime coverage.

Soviet weather satellites not only give cloud cover pictures, but report on ocean ice, snow cover on land, and have even given some geological information of value.

2. Experimental weather satellites

Weather cameras have also been carried on a few of the Molniya communications satellites. Advanced sensors related to passive microwave to determine ocean currents, ice fields under cloud cover, and soil moisture have been tested in Kosmos flights starting with Kosmos 243. An experimental Meteor 2 was orbited in 1975.

C. OTHER CIVIL APPLICATIONS

In time, Soviet navigation satellite use is likely to spread from purely naval to the merchant marine.

There are not yet any comprehensive Soviet Earth resources satellites of the unmanned variety. Techniques of Earth resources survey are under development largely within the manned program, supplemented by individual experiments in unmanned satellites.

Finally, the Russians also speak of versatile future cities in space serving many economic and human purposes, but these are not yet discussed in terms specific enough to be considered actual hardware programs.

VI. Soviet Military Space Activities

A. INTRODUCTION

The Soviet Union claims each individual space flight to be scientific in character, and in the early years many Soviet charges of aggressive military intent were made against the United States space program. As Soviet military space capabilities have grown in quantity, variety, and operational effectiveness, such charges against the United States have largely been muted, and a certain accommodation between the nations has been tacitly developed in this regard.

B. EXTENSION OF CIVIL TYPE SPACE ACTIVITIES TO MILITARY NEEDS

Weather reporting is generally an open activity, and military clients of such a system are not identifiable from the fact of such flights, but of necessity exist.

By now, it is suspected that the Molniya 1 satellites have moved from handling civilian television and telephone traffic to government and military uses. This is because this series is maintained actively while the newer Molniya 2 and 3 flights have taken on the tasks originally assigned to Molniya 1.

Geodesy and mapping could be either civil or military functions. The absence of identification of such flights by mission suggests that in the Soviet setting, they are still considered to be military.

C. NAVIGATION

The Russians have claimed a navigation satellite system for many years, but never have identified a specific payload as assigned to this use. They probably have gone the same technical route as the Americans in building a system which leaves the using submarines or surface ships passive, manipulating the signals heard in an onboard ship computer to establish the ship location in reference to the known position of the satellite.

D. SPACE RELATED CONTROL SYSTEMS

There is no sign the Russians yet operate a spaceborne traffic control system. They probably do use space links both for military command and control, and to maintain clandestine channels of communication.

E. ELECTRONIC FERRETING OR ELINT SPACE MISSIONS

Russian concern with all kinds of electronic intelligence is so well noted in their literature that one must assume many flights gather such intelligence, whether in the form of message traffic or of radar characteristics.

F. MINOR MISSIONS IN SPACE FOR THE MILITARY

A miscellany of minor missions such as environmental monitoring, testing of new components, and radar calibration are not viewed as especially sensitive military activities, but are not specifically identified by the Russians. They almost certainly make such flights.

G. EARLY WARNING SATELLITES

In an age of short time spans between initiation of missile launch and arrival of warheads at targets, early warning systems are a natural concern of military planners. It should be assumed that Soviet space flights include provision for early warning sensors.

H. MILITARY MANNED SPACE MISSIONS

In the Soviet case, military manned missions, beyond the use of military cosmonauts, is not admitted to, and must be inferred from the performance of some missions.

I. RECOVERABLE MILITARY OBSERVATION FLIGHTS

The Soviet Union only obliquely admits to use of military observation photographic flights in space, but the characteristics of their programs and the obvious need in both strategic and tactical applications are so great that their use must be probably the highest priority military mission under active application.

J. OCEAN SURVEILLANCE

Because naval vessels may operate under radio silence and maneuver to maintain positions under cloud cover where possible, an obvious application of space technology is an ocean surveillance system, using radar to penetrate the clouds. Such a Soviet system is now flying.

K. FRACTIONAL ORBIT BOMBARDMENT SYSTEM SATELLITES

While the United States has not considered fractional orbit bombardment satellites as cost effective, considering the alternative uses of limited funds, the Russians at least for some years held a different view, and worked vigorously to bring to operational level such a system. These satellites have not been flown since 1971.

L. MILITARY INTERCEPTOR/INSPECTOR/DESTRUCTOR SATELLITES

The United States abandoned its one-time commitment to development of a satellite co-orbit inspection system. The Russians pushed such a system vigorously, demonstrating intercepts at many altitudes, and exploding the inspectors after making close approaches.

M. GROUND BASED SPACE DETECTION AND DEFENSE SYSTEMS

Because the Russians have an antiballistic missile (ABM) system, one is not rash to assume they have at least a limited capability to intercept and destroy satellites with these same weapons.

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N. ORBITAL BOMBS STATIONED IN SPACE

There is no evidence the Russians have placed weapons of mass destruction in sustained orbit, and both major space powers are signatories of a treaty prohibiting such action.

O. ANALYSIS OF SOVIET FLIGHTS TO DISCOVER THE MILITARY COMPONENT

It is possible to match the characteristics various military space systems should have to be effective against the characteristics of actual Soviet flights which have not been specifically identified by the Russians as to purpose. The repetitive patterns of most of these flights make their mission identification fairly easy to a reasonable degree of certainty, although some judgments may have to be altered with time. Categories found include:

1. Minor Military Missions

These are launched by the B–1 or the C–1 from Plesetsk and less often today from Kapustin Yar.

2. Electronic Ferret or Elint Missions

These are launched by the C–1 or the A–1 from Plesetsk.

3. Navigation and Navigation/Geodetic Missions

These are launched by the C–1 from Plesetsk.

4. Obscure Missions Operating in the Store-dump Mode

Whether launched from Plesetsk singly by the C–1 to about an 800 kilometer altitude, or eight at a time by the C–1 to about a 1,500 kilometer altitude, these flights probably serve communications purposes related to command and control or tactical communications, or for other clandestine purposes.

5. Targets for Interception and the Interceptors Themselves

The C–1 from Plesetsk has been used to put up targets, and the F–1–m from Tyuratam has put up both targets and the maneuverable interceptors themselves.

6. Fractional Orbit Bombardment Satellites

For a period of six years, the F–1–r was used at Tyuratam to fly simulated bombs about 95 percent or so of the distance around the Earth back to home territory, but this was suspended in 1971.

7. Military Ocean Radar Surveillance

The F–1–m maneuverable satellite is being used increasingly for ocean surveillance, and at the end of the mission, the "hot" radioactive power source is being moved to a higher orbit from which it will not decay for many centuries.

8. Early Warning Satellites

The A–2–e is used to put early warning satellites into 12-hour orbits from Plesetsk, most likely for this purpose. It is possible the first similar use has been made of the D–1–e at Tyuratam to put such a payload into a 24-hour orbit.

9. Military Observation Photographic Missions

The largest single element of the entire Soviet space program is

made up of recoverable missions which stay in low circular orbit for periods up to 14 days and then return to Kazakhstan. They are launched both at Plesetsk and at Tyuratam, using the A–2 launch vehicle.

Analysis, particularly in the public domain by the Kettering Group of the United Kingdom, sorts these flights into various subsets by maneuvering capabilities, and telemetry and beacon formats. These have made it possible to estimate the categories of camera resolutions and often to identify the specific Earth targets which they watch.

Overall, the ratio of military uses to civil uses of space launches by the Soviet Union is two to one.

VII. Projections of Soviet Space Plans

Soviet space plans for the future are commented upon extensively by Russian spokesmen, but usually without specific timetables. So much is predicted that one realizes not all the goals can be attained in the near term. Hence, the task is to estimate intentions rather than just their broad technical capabilities. Such coming trends may be estimated both from the clues of precursor flights and subsystems development and from a careful reading of how they make their public predictions. The best estimates of the future may fail to materialize if external events intervene, or if their policies are changed.

A. General Technical Capabilities

They have now built up a complex of industry, experience, and human talent which is capable of supporting indefinitely their present high level of space flight, and there is no reason to assume there are presently any plans for retrenchment. Further growth may come, but at a slower rate, unless they put into service a reusable space shuttle, which could provide a "quantum jump" in what they do. The long awaited very large lift vehicle, the G class, will probably appear, and permit some direct launches of large payloads without the necessity for orbital assembly to the same degree otherwise required.

B. Unmanned Space Flights

Their existing activities in science, weather reporting, and communications should continue to grow in operational effectiveness. One can expect further flights to the Moon of sample retrievers, roving vehicles, and orbiters. Both Mars and Venus will continue to receive attention when the windows for launch are favorable. Later, there will be Soviet flights inward to Mercury, outward to the giant planets, and new missions to comets, planetoids, and out of the plane of the ecliptic.

Military uses are already so large a part of the total that they will continue to expand upon and perfect the great variety of activities currently being pursued. The question of more threatening missions is one that turns both on the issues of arms controls and of the possible appearance of new technologies which could change prevailing assumptions as to what is now "reasonable".

C. MANNED SPACE FLIGHT

Several more years of flights using the evolving Salyut station and the Soyuz ferry craft should be expected. These operations will develop toward longer and longer life stations with resupply and refurbishment.

Manned lunar landing seems to have been delayed longer than was expected five years ago, but has not been written out of the realm of possibilities. All the hardware ingredients which were being rushed to readiness in the late 1960's and shortly thereafter are still in existence with active production lines. When the Russians are confident their systems will work reliably, they will visit the Moon, probably using a combination of Earth orbit rendezvous and lunar orbit rendezvous.

Manned interplanetary flight is not only an announced goal in speeches, but a strong likelihood in terms of the work being done on space medicine and life support systems. An operational Soviet space shuttle would move plans for such work from the merely technically possible to the economically possible.

For the more distant future, human settlements on other celestial bodies and study of interstellar travel are of interest to the Russians, but not yet in the form of concrete plans.

D. SOVIET PHILOSOPHY TOWARD THEIR SPACE PROGRAM

The Russians have taken pride in their space accomplishments, and have not been loath to exploit the prestige associated with their successes. Space technicians seem to have convinced the political leadership, which often has an engineering background, of the economic necessity and benefit of pursuing an expanding program of exploration and application.

They have not neglected science and discovery for its own sake. If this has involved any delay in improving the lot of the consuming public, it is part and parcel of a broader philosophy of sacrificing the present for Communist "pie in the sky".

For a system which flaunts its atheism, there is a certain element of secular religion in the official attitude that Soviet man through his mastery of science and technology can control his destiny for the good of his system of society and government.

Overall, their space program is pursued consistently, in orderly fashion, seeking multiple goals; and the investment in support of these ends is substantial, and probably in real terms is in excess of the U.S. program at its previous peak.

CHAPTER ONE

OVERVIEW, SUPPORTING FACILITIES AND LAUNCH VEHICLES OF THE SOVIET SPACE PROGRAM

By Charles S. Sheldon II*

I. Overall Trends in Flights

The purpose of this section is to provide a perspective on the trends of development of the Soviet space program, including data on its general composition before turning in detail to particular components. To this end, statistical tables have been developed which will cover the entire period of flight operations even beyond the years on which this report is concentrated. It may be noted by the discerning reader that over a period of time some numbers in historical tables are modified from those previously published. This is because even at this late date, there are some new disclosures and also fresh interpretations of old data based upon more recent events which permit a refinement and more meaningful interpretation of what was even less perfectly understood earlier. In one sense, there never will be final figures for many tables. Not only do governments maintain policies of secrecy, but many numbers are based upon arbitrary definitions which are only occasionally spelled out in sufficient detail to be able to understand why two tables which purport to cover the same events come up with different numbers. For the most part, Soviet official numbers show fewer variations than do their U.S. counterparts. This may be because when an early estimate is made and published, the Soviet authorities continue to use those data, even if their own computers later could make available slightly different refined figures.

While this study does not present a complete comparison of Soviet space data with that of other nations because it was not called for in our terms of reference, some of the tables which follow do include worldwide coverage in order to provide a perspective on the Soviet effort.

The basic data come from national announcements such as TASS bulletins and National Aeronautics and Space Administration (NASA) press releases, plus the compilations of several national agencies. Most of the basic worldwide record maintained by the United States is compiled by Norad (North American Air Defense Command), a joint U.S.-Canadian activity at Colorado Springs. Norad data are passed to the Goddard Space Flight Center which selects a part of these data and may add a few items of NASA origin which are then issued every other month. There is a corresponding activity in the United Kingdom. The Royal Aircraft Establishment at Farnborough, Hants, has a satellite analysis group headed by Desmond

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G. King-Hele which once a month issues a limited circulation tabulation combining data from many sources to provide more data than the basic U.S. public lists show. These preliminary monthly lists are cumulated and corrected from time to time. In addition to the above official sources, similar unofficial lists, often with additional details, are carried semi-annually in *Flight International* in London, bimonthly in *Spaceview* in Amsterdam, and monthly in *Spaceflight* in London.

A. GROSS STATISTICS

Table 1–1 which follows is a world summary by years of launches and payloads to Earth orbit or beyond, successes and failures to the extent known or estimatable for each country. As such, it reveals something about trends, but nothing about the size, the effectiveness, or the utility and significance of each flight. According to the table, the Soviet Union reached a peak in number of successful launches in 1975. This contrasts with the U.S. peak of 1966 from which declines have brought this country down by about 62 percent. The flights of all other nations are minor by comparison with the two space leaders.

The record on payloads to Earth orbit is somewhat more erratic because the count includes a scattering of flights in which a considerable number of payloads were sent up together. Even so, approximately the same trends are reflected as for launches. For the so-called escape payloads, those sent to the vicinity of the Moon, the planets, or around the Sun, the number of payloads is much smaller. In this case there is no single Soviet peak, and the U.S. peak was in 1967.

One can be reasonably sure that the record of successful launches is complete. The number of payloads may be nearly right, although there is always a chance of a pickaback which for some reason was not announced, or a piece of debris was thought to be a useful payload in the absence of information to the contrary. On the other hand, the record of failures is very problematical overall. The U.S. count on launch failures is probably accurate despite the reluctance of our Government to give prominence to these failures. The number of U.S. payloads lost through failure to reach orbit is more suspect because there is no legal obligation to report how many payloads a launch vehicle may have contained. The counts for all other non-Communist nations and their international agencies are probably accurate. There is no reliable public record of possible Soviet or Chinese launch failures. Only two Soviet launch failures have been acknowledged by that nation. (These were the Soyuz launch of April 5, 1975 and a launch on June 3, 1975 which included a Swedish experiment.) In addition two Soviet launch failures were officially publicized by the U.S. Government. (These were the Mars attempts of October 10 and October 14, 1960.) However, because of the Soviet use of the orbital launch platform technique for sending payloads either to deep space or to eccentric Earth orbit, a strong inferential case based upon time of launch and behavior of debris can be made that 22 payloads intended for escape missions fell short of that objective, and count as "failures" even though they were in most cases Earth orbital "successes". In some of these cases, the Soviet Government did not even acknowledge the fact of launch. For the purposes of this table, judgments on success or failure of launches and payloads are based exclusively on whether

hardware attained Earth orbit or "escape", not on whether the payloads functioned and returned data. There is no public basis for classifying by operational effectiveness the payloads of most of the Soviet flights and those of the U.S. Department of Defense.

There were two choices open to the analyst in estimating the unreported and unmeasurable Soviet or Chinese failures. One was to compile a list of rumors (as has been done by J. A. Pilkington in the United Kingdom) ; the other was to argue that development of a common technology has probably moved at a somewhat similar pace in different countries, and therefore the known failure rate of the United States could afford order of magnitude ratios to apply to the records of those countries which do not admit to failure. The latter course has been followed. Neither the rumor approach nor the common ratio approach can be counted upon to be accurate. What would not be satisfying would be to accept uncritically the oft-repeated early Soviet claim that their program unlike the American has no failures. In the 1970's the Russians issued a feature length motion picture, "The Taming of the Fire", which was a fictionalized account of the life of rocketeer Sergey Korolev, and this included footage of one spectacular near launch site failure after another, to reflect the problems of the days Korolev was developing the standard launch vehicle. The pictures appeared to be genuine, and in any case represented a shift in policy by acknowledging that all space programs have their difficulties. The directly measurable Soviet failure rate for their deep space program runs higher than a simple ratio comparison with the United States would suggest, but this may have something to do with their use of the orbital launch platform technique, and poorer worldwide support facilities for this phase of their flights.

TABLE 1-1.—WORLDWIDE RECORD OF KNOWN SPACE LAUNCHINGS—SUCCESSES

Year	Launches								Payloads to Earth orbit								Escape payloads to Moon, beyond	
	United States	U.S.S.R.	France	Japan	Italy	China	Australia	United Kingdom	United States	U.S.S.R.	France	Japan	Italy	China	Australia	United Kingdom	United States	U.S.S.R.
1957		2								2								
1958	5	1							5	1								
1959	10	3							9								1	3
1960	16	3							16	3							1	
1961	29	6							35	7								1
1962	52	20							55	25							4	1
1963	38	17							62	19								1
1964	57	30							69	37							4	2
1965	63	48	1						93	68	1						4	7
1966	73	44	1						94	47	1						7	5
1967	57	66	2		1		1		78	74	2		1		1		10	1
1968	45	74							61	81							3	4
1969	40	70							58	76							[1] 8	4
1970	29	81	2	1		1			36	98	3	1		1			3	5
1971	31	83	1	2	1	1		1	45	107	1	2	1	1		1	8	7
1972	31	74		1					33	106		1					8	3
1973	23	86							23	122							3	7
1974	22	81		1	2				27	111		1	2				1	3
1975	28	89	3	2		3			30	135	4	2		3			4	4
Total	649	878	10	7	4	5	1	1	829	1,119	12	7	4	5	1	1	69	58

[1] Additionally, the United States sent 1 piece of debris from an Earth orbital payload to escape.

FAILURES

Year	Launches: United States	Launches: U.S.S.R.	Launches: France	Launches: Japan	Launches: China	Launches: United Kingdom	Launches: ELDO	Payloads to Earth orbit: United States	Payloads to Earth orbit: U.S.S.R.	Payloads to Earth orbit: France	Payloads to Earth orbit: Japan	Payloads to Earth orbit: China	Payloads to Earth orbit: United Kingdom	Payloads to Earth orbit: ELDO	Escape payloads to Moon, beyond: United States	Escape payloads to Moon, beyond: U.S.S.R.
1957	1							1								
1958	12							8							4	
1959	10							9							2	
1960	13	2						12	2						2	2
1961	12							12							2	1
1962	7							12							1	5
1963	8							11								2
1964	7							8								1
1965	7							7							1	2
1966	4			2				12			2				1	1
1967	3			1				4			1					3
1968	3						1	15						1		
1969	1			1			1	1			1			1	1	2
1970	1			1		1	1	1			1		1	1		1
1971	3		1				1	2		1				1	1	1
1972	2							2								1
1973	2		1	1				2		2	1					
1974	1							2								
1975	3	2						4	2							
Total	100	134?	2	6	17	1	4	125	169?	3	6	1?	1	4	15	22+?

NOTES

1. The most glaring omission from the table is the year-by-year count of Soviet space failures (and perhaps Chinese space failures) caused by secrecy in this regard. Only 2 Soviet failures have been announced by the United States and 2 Soviet failures announced by that government. The total failures listed for the U.S.S.R. and China carry questionmarks because they are only estimates proportional to U.S. losses.

2. Soviet failures in escape missions to the Moon and planets are more nearly correct because that portion of such flights which at least achieved Earth orbit left tell-tale traces of debris. Such payloads counted as "successes" along with their Earth orbital launch platforms even though they were also listed as escape failures. There are probably additional escape mission failures which did not make even Earth orbit and hence understate the failure record.

3. While Chinese failures have also been estimated, the success record is too small to give much validity to any count.

4. It should be noted that the number of spacecraft listed exceeds the number of launches because some launches have carried multiple payloads.

5. The Soviet count of payloads includes their heavy sputnik orbital launch platforms called either Tyazheliy Sputnik or Nositel Sputnik. Some 135 of these have accompanied escape missions and high orbit missions such as those of the Molniya communications satellites.

6. Payloads which have flown as far from Earth as lunar orbit are counted in the escape category rather than with Earth satellites.

7. Two U.S. payloads intended to fly as far as the Moon or beyond stayed in Earth orbit and hence are counted as Earth orbital successes and escape failures.

8. The success or failure test applied for purposes of this table is solely that of whether orbit or escape was attained when so intended. Whether the orbit was useful or whether the instrumentation worked is not measured because not enough information is supplied by most launching countries to draw consistent conclusions. NASA publishes its own mission successes and failures by its own more stringent criteria than could be applied here.

9. Payloads are defined as functional objects, usually emitting signals, but used occasionally as specifically designed passive calibration devices, with these objects counted as separate payloads if they were intended to operate independently whether in fact they did or did not separate in every instance.

10. Included among the payload successes and failures, the latter in parens, put up by the United States and credited to that Nation are: Intelsat—20(2), NATO—2, ESRO—7(1), ESA—1, France/Germany—2, Canada—7, United Kingdom—8(1), Germany—4, France—2, Australia—1 supplemental, Italy—1, Netherlands—1, Spain—1 supplemental. Of U.S. launches, 4 were performed by Italy (in 1970, 1971, 1972 and 1975). One additional Italian launch was for the United Kingdom. One French launch was jointly for France and Germany. The Soviet Union has had 14 Interkosmos launches for the Soviet Bloc, 4 French including 2 supplemental, and 1 Indian. Both the United States and the U.S.S.R. have carried many individual experiments of other countries.

SOURCES: The success data are derived from the Goddard Satellite Situation Report and the corresponding report of the Royal Aircraft Establishment (RAE). U.S. failure data are from the President's annual reports to Congress on aeronautics and space activities. Other failures are based upon either press releases of the governments concerned or upon interpretations of the Goddard and RAE source materials referenced above. Estimated failure totals are derived from simple ratios compared with the U.S. record.

B. BREAKDOWN BY CATEGORIES

Table 1–2 which follows analyzes Soviet payload statistics by the probable mission categories, including some tentative comparisons with the United States. For a large number of Soviet flights such data are not published, and a variety of analytical techniques have had to be applied to come up with this approximation of the probable missions. Each of these categories will be discussed in some detail further into this section. Some flights can be tagged because those of a particular series have been given a specialized name and usually described in fair detail. But most have been thrown under the catchall label "Kosmos"—which means Space. The press release issued at many of these launches references the release in 1962 which accompanied Kosmos 1 which listed so many potential missions as to account for almost anything. In the instance of the Kosmos flights, they must be studied for all known characteristics of time and place of launch, of orbital elements, of total time in orbit until decay, and of measurable behavior in orbit. Some of these flights later have their results published in articles in the Soviet scientific journals. Then inferences can be made about others of similar characteristics. For example, years before the United States announced that it had been operating previously unannounced military weather satellite program, it was evident to close observers that when a succession of payloads were put into 960 kilometer circular orbits, just retrograde enough to be Sun-synchronous, this would almost have to be for the purpose of taking low resolution pictures such as those used for weather reporting purposes. Likewise, when the Soviet Union puts up heavy satellites about 30 times a year and calls them down from low circular orbit after just a few days in orbit, one has to think of high resolution pictures recorded on film which will be analyzed in laboratories on Earth. Similar assessments based on logic and inference give a fair basis for defining the missions of most spacecraft.

There are inevitably some arbitrary classification problems. For example, should the first flight in a new series only later defined and made fully functional be classed with that series, or listed under "vehicle tests"? In general, the decision has been to list them with the emerging program. Then there are flights which may serve at least two major purposes. Here somewhat arbitrary choices have been made based upon the best estimate of the dominant purpose.

TABLE 1-2.—SUMMARY OF SOVIET SPACE PAYLOADS BY MISSION CATEGORY (WITH U.S. COMPARISONS)

Mission Category	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Soviet Total	U.S. Total
PRIMARILY CIVILIAN																					
Earth Orbital Science	1	1				7	2	8	4	4	5	11	4	10	8	13	10	9	14	111	158
Earth Orbital Engineering																1			1	2	53
Vehicle Tests							1	1	1	1										4	13
Communications								1	2	2	3	3	2	5	3	6	8	8	11	54	107
Weather							2	1	2	2	4	2	2	5	4	3	2	5	4	38	63
Geodesy																					18
Earth Resources																					2
Earth Orbital Man-Related or Biology	1			3	2			1	1	2	3	4		1	2	1	5	5	3	34	11
Earth Orbital Manned					2	2	2	1	1		1	1	5	1	3		2	5	3	29	20
Lunar Man-Related or Biology											2	3	1	2						8	16
Lunar Manned																					20
Moon (Unmanned)			3				2		5	6		1	3	3	3	2	1	3		32	23
Venus, Mercury					2	3	1	2	3		2		2	2		2			4	23	3
Mars, Jupiter, Saturn				[2]		3		1	1						5		6			16	11
Interplanetary Medium																					6
PRIMARILY MILITARY																					
Military Recoverable Observation						5	7	12	17	21	22	29	32	29	28	29	35	28	34	328	220
Mapping and Geodesy																					
Minor Military (Environmental Monitoring, Radar Calibration, Electronic Ferret?)								2	5	4	8	9	12	11	11	9	9	8	6	94	90
Elint, Ferret									5		1	2	2	4	6	5	5	6	6	42	
Navigation and Geodesy								3	6		2	3	4	3	4	5	4	6	6	46	31
Military Communications, Store-Dump								2	11		1	1		9	18	18	25	17	26	128	
Early Warning											1	1				1	1	1	2	7	33
Fractional Orbit Bombardment System										2	9	2	2	2	1					18	
Ocean Surveillance											1	1		1	2	1	1	2	3	12	
Inspection Targets											1	2	1	1	3	1				9	
Inspector Destructors												2		2	3					7	
Subtotal	2	1	3	3	6	20	17	35	64	44	66	77	72	91	104	97	114	103	123	1,042	898
Orbital Launch Platforms				[2]	2	6	3	4	11	8	9	8	8	12	10	12	15	11	16	135	
Total	2	1	3	3	8	26	20	39	75	52	75	85	80	103	114	109	129	114	139	1,177	898

NOTES

1. This table was derived by using analytical techniques described in the main body of the report especially Chapter Two, in order to classify Soviet payloads by probable principal mission to the extent a reasonable assignment could be made.

2. The subdivisions of missions selected for use in this table were chosen to reflect categories discussed in the text. As the text notes, many payloads have more than one purpose, and to avoid double counting the listing for a given flight had to assume a principal purpose. This is not always easy In such cases as geodesy and navigation, early warning and geophysical reporting, and vehicle tests and precursor flights for specific applications.

3. Deciding which missions were primarily civilian in character and which military was also difficult and somewhat arbitrary. For example, all Molniya communications payloads were counted as civilian even though probably much military traffic is carried; but Kosmos flights also believed to be serving communications purposes (probably store-dump, from their relatively low altitude) were counted as military. Geodetic flights could be civilian as many are in the United States, but because they have not been acknowledged by individual flight, they were counted in the Soviet case as all military.

4. A few headings were selected to make easier comparisons with the United States.

5. Because the U.S. Department of Defense does not define many of the missions for its own flights, the column of comparisons does not reflect an official U.S. position, but rather a grouping of flights by their external characteristics, using essentially the same techniques as were applied to Soviet flights not defined by the Soviet government.

SOURCES: This table drew upon the basic log of all Soviet space flights contained in Appendix A, and as grouped by launch site, launch vehicle, and inclination in Table 1-3 in order to find appropriate groupings for flights.

The column of U.S. data was drawn primarily from source data contained in the annual reports of the President to Congress on aeronautical and space activities.

Table 1–3 in effect provides some of the back-up for Table 2 by listing all Soviet flights by years, by launch site, by flight inclination, by launch vehicle, and by class of name.

Table 1–4 is a simpler array of the same number of flight totals by year, but groups them by the names if any assigned by the Soviet Government itself.

TABLE 1-3.—DETAILED SUMMARY OF SOVIET SPACE PAYLOADS BY LAUNCH SITE, LAUNCH INCLINATION AND LAUNCH VEHICLE

Payload	Inclin-ation	Launch vehicle	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Total
KAPUSTIN YAR																						
Kosmos—Weather	48-9	B-1											1			1						2
Interkosmos—Science	48-9	B-1													2	2	1	1	1			7
Kosmos—Science	48-9	B-1						7	4	4	2	3	4	6								31
Kosmos—Minor Military	48-9	B-1								2	5	4	2	2	2	1		1				19
Kosmos—Military Communications	48-9	B-1								2												2
Kosmos—Science	50-1	C-1																	1			1
Interkosmos—Science	50-1	C-1																		1		1
Aryabhata—Science	50-1	C-1																			1	1
Total								7	4	8	7	7	7	8	4	5	1	2	2	1	1	64
TYURATAM																						
Kosmos—Communications, Early Warning	0	D-1-e																		1	1	2
Molniya 1-S—Communications	0	D-1-e																		1	1	1
Raduga—Communications	0	D-1-e																				1
Unacknowledged—FOBS Related	50	F-1-										2										2
Kosmos—FOBS	50	F-1-r											9	2	1	2	1					15
Kosmos—FOBS Related	50	F-1-													1							1
Kosmos—Manned Precursor	50-1	A-2																		1		1
Kosmos—Military Recoverable Observation	51-2	A-1								4			1									5
Kosmos—Military Recoverable Observation	51-2	A-2									2	4	5	7	4	3						25
Kosmos—Military Improved Recoverable	51-2	A-2												1	2	1	5	1	2	1		13
Unacknowledged—Pickaback	51-2	A-2												1	1		1					3
Kosmos—Soyuz Precursor	51-2	A-2										1	3	3				1	2	3	1	14
Soyuz—Manned Ship, or Unmanned	51-2	A-2											1	2	5	1	2		2	3	4	20
Kosmos—Manned Precursor	51-2	A-2-m														1	2					3
Proton—Science	51-2	D-1												1								1
Kosmos—Salyut	51-2	D-1																	1			1
Salyut—Space Station	51-2	D-1															1		1	2		4
Kosmos—Zond Precursor	51-2	D-1-e											2									2
Zond—Circumlunar Manned Precursor	51-2	D-1-e												3	1	1						5
Kosmos—Manned Precursor	51-2	D-1-m														1						1
Unacknowledged—Tyazheliy Sputnik	51-2	A-2-e									4	6	3	1	2	3	2	2				23
Unacknowledged—Tyazheliy Sputnik	51-2	D-1-e											2	3	4	4	5	1	5	4	4	32
Kosmos—Eccentric Orbit	51-2	A-2-e											1									1
Kosmos—Escape Failure	51-2	A-2-e									1	1	1			1		1				5
Kosmos—Escape Failure	51-2	D-1-e													2		1					3
Luna	51-2	A-2-e									1	5		1								7
Luna	51-2	D-1-e													1	2	2	1	1	2		9
Venera	51-1	A-2-e									2		1		2	1		1				7
Venera	51-2	D-1-e																			2	2

TABLE 1-3.—DETAILED SUMMARY OF SOVIET SPACE PAYLOADS BY LAUNCH SITE, LAUNCH INCLINATION AND LAUNCH VEHICLE—Continued

Payload	Inclination	Launch vehicle	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Total
Mars	51-2	D-1-e															2		4			6
Unacknowledged—Supplemental Escape	51-2	D-1-e														1	3	1		1	2	8
Interkosmos—Science	51-2	A-2																1				1
Kosmos—Recoverable Biological	51-2	A-2										1										1
Kosmos—Military Communications, Multiple	56	C-1								3	21											24
Kosmos—Military Communications, Single	56	C-1									1		1	1								3
Polet—Maneuverable Test Vehicle	58-9	A-m							1	1												2
Elektron—Science	61	A-1								4												4
Kosmos—Interceptor Destructor	62-6	F-1-m												2		2	3					7
Kosmos—Interception Target	62-5	F-1-m												1		1						2
Kosmos—Ocean Surveillance	65	F-1-m											1	1		1	2	1	1	2	3	12
Kosmos—Test or Military	62-4	F-1-m											1	1	1					1	1	5
Proton—Science	63-4	D-1									2	1										3
Unacknowledged—Tyazheliy Sputnik	64-5	A-2-e					1	6	3	4	7	2	4	4	2	1			2			36
Kosmos—Communications	64-5	A-2-e								1			1	1								3
Molniya 1	64-5	A-2-e									2	2	3	3	2	1		1	2			16
Unacknowledged—Escape Failure	65	A-2-e				(2)	1	5	1													7
Kosmos—Escape Failure	65	A-2-e							1	1	1											3
Venera	65	A-2-e					1															1
Mars	65	A-2-e						1														1
Zond—to Venus or Mars distances	65	A-2-e								2	1											3
Tyazheliy Sputnik	65	A-2-e					1															1
Unacknowledged—Tyazheliy Sputnik	65	A-2-e																3	1		1	5
Luna	65	A-2-e							1		3											4
Prognoz—Science	65	A-2-e																2	1		1	4
Sputnik	65	A	2	1																		3
Korabl Sputnik—Vostok Precursor	65	A-1				3	2															5
Vostok—Manned Ship	65	A-1					2	2	2													6
Kosmos—Voskhod Precursor	65	A-2								1	1											2
Voskhod—Manned Ship	65	A-2								1	1											2
Kosmos—Test Vehicle	65	A-1-m									1	1										2
Kosmos—Weather	65	A-1								1	2	2										5
Kosmos—Military Recoverable Observation	65	A-1						5	6	5	6	6	1									29
Kosmos—Military Recoverable Observation	65	A-2							1	3	8	5	1	3	7	2						30
Kosmos—Military Improved Recoverable	65	A-2												2		7	8	9	5	7	8	46
Unacknowledged—Pickaback	65	A-2												1		1	1				2	5
Kosmos—Military Recoverable Observation	69-71	A-1									1											1
Kosmos—Military Improved Recoverable	69-71	A-2												1	1			1	1	1	4	9
Unacknowledged—Pickaback	69-71	A-2												1								1
Luna	74	A-1			3																	3
Total			2	1	3	3	8	19	16	31	68	39	42	47	39	38	41	27	31	30	35	520

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Molniya 1—Communications	62-3	A-2-e								1	2	3	6
Molniya 2—Communications	62-3	A-2-e								2	3	4	9
Molniya 3—Communications	62-3	A-2-e									1	3	4
Kosmos—Early Warning	62-3	A-2-e							1	1	1	1	4
Unacknowledged—Tyazheliy Sputnik	62-3	A-2-e							1	4	7	11	23
Kosmos—Biological Science	62-3	A-2								1	1	1	3
Kosmos—Military Improved Recoverable	62-3	A-2								1	10	13	24
Unacknowledged—Pickaback	62-3	A-2								1	3	4	8
MAS—French Technology Test	62-3	A-2-e										1	1
Molniya 1—Communications	65-6	A-2-e					4	2	2	1			9
Molniya 2—Communications	65-6	A-2-e						1	3	2			6
Unacknowledged—Tyazheliy Sputnik	65-6	A-2-e					4	3	5	3			15
MAS—French Technology Test	65-6	A-2-e							1				1
Kosmos—Interception Target	65-6	C-1						3	1				4
Kosmos—Science	65-6	C-1						1					1
Kosmos—Military Recoverable Observation	65-6	A-1	2	3									5
Kosmos—Military Recoverable Observation	65-6	A-2		8	11	12	5						36
Kosmos—Military Improved Recoverable	65-6	A-2				3	4	8	10	12			37
Unacknowledged—Pickaback	65-6	A-2				1		2	3	1			7
Kosmos—Military Improved Recoverable	67	A-2										1	1
Interkosmos—Science	71	B-1							1				1
Kosmos—Science	71	B-1			1		2		1				4
Kosmos—Minor Military	71	B-1		4	5	9	8	10	7	8	6	4	61
Kosmos—Military Recoverable Observation	72-3	A-1	1										1
Kosmos—Military Recoverable Observation	72-3	A-2	3	3	2	2	1						11
Kosmos—Military Improved Recoverable	72-3	A-2					3	5	5	13	5	3	34
Unacknowledged—Pickaback	72-3	A-2					1		2	3	2	2	10
Kosmos—Ferret in Low Orbit	74	C-1		1	2	2	3	5	3	4	4	4	28
Kosmos—Navigation in Low Orbit	74	C-1		2	1	2	2						7
Kosmos—Military Communications-Intermediate	74	C-1					1	2	2	1	1	2	9
Kosmos—Navigation in High Orbit	74	C-1					1	2	2			2	7
Kosmos—Navigation, Geodesy in Highest	74	C-1			2	2		2	1	1	2	1	11
Kosmos—Military Communications, Multiple	74	C-1					8	16	16	24	16	24	104
Kosmos—Science	74	C-1					2	1					3
Oreol—French Science	74	C-1						1		1			2
Interkosmos—Science	74	C-1								1	1	1	3
Kosmos—Military	74	C-1									1		1
Kosmos—Weather	81	A-1		3	2								5
Meteor 1—Weather	81	A-1				2	4	4	3	2	5	3	23
Meteor 2—Weather	81	A-1										1	1
Kosmos—Ferret	81	A-1					1	1	2	1	1	2	8
Kosmos—Military Recoverable Observation	81	A-2			2	1	1						4
Kosmos—Military Improved Recoverable	81	A-2					2	2	3	2	4	5	18
Unacknowledged—Pickaback	81	A-2							2	1	2	2	7

TABLE 1-3.—DETAILED SUMMARY OF SOVIET SPACE PAYLOADS BY LAUNCH SITE, LAUNCH INCLINATION AND LAUNCH VEHICLE—Continued

Payload	Incli-nation	Launch vehicle	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Total
Kosmos—Science	82	B-1														1						1
Kosmos—Minor Military	82	B-1											2	2	1	2	1	1	1		1	11
Kosmos—Navigation in High Orbit	83	C-1																1	3	4	2	10
Kosmos—Navigation, Geodesy in Highest	83	C-1																1			1	2
Kosmos—Military	83	C-1																		1		1
Interkosmos—Science	83	C-1																			1	1
Total												6	26	30	37	60	72	80	96	83	103	593
Kapustin Yar								7	4	8	7	7	7	8	4	5	1	2	2	1	1	64
Tyuratam			2	1	3	3	8	19	16	31	68	39	42	47	39	38	41	27	31	30	35	520
Plesetsk												6	26	30	37	60	72	80	96	83	103	593
Grand total			2	1	3	3	8	26	20	39	75	52	75	85	80	103	114	109	129	114	139	1,177

NOTES

1. Because the greatest part of the Soviet space program is blanketed under the cover name of Kosmos, it is necessary to make an analysis of all flights by their orbital characteristics as a first step toward determining their approximate missions as assigned in Table 1-2. Chapters two and six will go through the analytical steps which can then take each collection of flights by their characteristics to determine their possible missions. This table only goes so far as to look at launch site, launch vehicle, and inclination. The full analysis requires further looks at apogee, perigee, orbital behavior and orbital life.

2. The totals by year in this and other tables on payloads all build to the same numbers.

3. This table borrows from the later analysis by assigning a possible mission as well as listing the name (or noting the absence of a name).

4. The inclination listed is that announced by the Soviet TASS agency if available; otherwise it is that given by the Royal Aircraft Establishment (RAE) or the Goddard Satellite Situation Report. In all cases it has been rounded to the nearest whole degree, with variation indicated by hyphenated numbers of degrees.

5. The launch vehicle has been determined by matching announced and pictured vehicles at given sites and with known missions to others flown at the same inclinations and behaving in similar fashion. These estimates are aided by the work published by the RAE, based on optical or radar data on spent rocket casings which permit the sorting out of the several kinds of upper stages, and by the telemetry and beacon signals detected and compiled by the Kettering Group in the United Kingdom.

6. Such a table may require further subdivision or reorganization as later discoveries about earlier flights are made either through Soviet disclosures or through Western analysis. Often precursors are not understood until later operational missions give fresh insights into what was earlier unclear.

SOURCES: Data summarize listings from the chronological log contained in Appendix A, based on Soviet TASS bulletins, plus the additional flights or changes in orbital elements detected and revealed by the RAE, the Kettering Group or the Goddard Satellite Situation Report.

TABLE 1-4—SUMMARY OF SOVIET SPACE PAYLOADS BY NAME

Name	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Total
Sputnik	2	1																		3
Luna			3				1		4	5		1	1	2	2	1	1	2		23
Korabl Sputnik				3	2															5
Tyazheliy Sputnik					1															1
Venera					1				2		1		2	1		1			2	10
Vostok					2	2	2													6
Kosmos						12	12	27	52	34	61	64	55	72	81	72	85	74	85	786
Unannounced (& Pickabacks)				(2)	1	5	1			2		3	2	3	7	8	7	8	12	59
Mars						1									2		4			7
Polet							1	1												2
Elektron								4												4
Zond								2	1			3	1	1						8
Voskhod								1	1											2
Molniya 1									2	2	3	3	2	5	2	3	4	2	3	31
Proton									2	1		1								4
Soyuz											1	2	5	1	2		2	3	4	20
Meteor 1													2	4	4	3	2	5	3	23
Interkosmos													2	2	1	3	2	2	2	14
Salyut															1		1	2		4
Molniya 2															1	3	4	3	4	15
Oreol															1		1			2
MAS																1		1		2
Prognoz																2	1		1	4
Molniya 1–S																		1		1
Molniya 3																		1	3	4
Aryabhata																			1	1
Meteor 2																			1	1
Radvga-Statsionar																			1	1
Subtotal	2	1	3	3	7	20	17	35	64	44	66	77	72	91	104	97	114	103	123	1,043
Implicit Tyazheliy Sputnik					1	6	3	4	11	8	9	8	8	12	10	12	15	11	16	134
Total	2	1	3	3	8	26	20	39	75	52	75	85	80	103	114	109	129	114	139	1,177

NOTES

1. This is a straight-forward listing of Soviet payloads by the names announced by the Soviet TASS agency (plus those unannounced and hence nameless) in the order of appearance of the names.

2. The unannounced payloads have been included so that totals in the table will match other tables, and these are flights either discovered by Western sensors, or inferred from the nature of the flights.

3. The orbital launch platforms used for escape missions and more extreme Earth orbits when first used were named Tyazheliy Sputnik 4 and 5. After that time, this hardware technique has been referenced by the TASS bulletins, but not assigned formal names.

4. Some flights carry pickaback payloads which have not been identified as such by TASS, but the objects have been found in orbit by Western sensors, and the experiments have ultimately been acknowledged in many cases by the Russians. In addition to these Earth orbital pickabacks which separate during flight from the main payload, certain flights carry other separate functional objects which count as payloads. These include the counts that come from missions which have both an orbital or fly-by bus which continues to function as well as a functional planetary lander; also there are the Moon landers which continue to function and which also launch a return rocket toward Earth carrying a lunar sample.

5. Objects known and inferred to have been intended to function separately are counted whether in fact they did (for example, a payload which reached Earth orbit but which failed to separate from its orbital launch platform, when intended to continue to the Moon or planets).

SOURCES: TASS bulletins, primarily, plus U.S. and British disclosures, all as carried in Appendix A·

C. COMPARATIVE WEIGHTS OF PAYLOAD

There is no certain way of finding out the exact weights of payload carried to orbit by each nation as only selectively is such information released by the governments concerned. Further, the actual weights of payload, announced or estimated, suffer from two statistical problems. There is no universal definition of what constitutes payload, and the significance of a given payload weight is modified by the velocity imparted to it.

A payload may be defined by some reports as the total weight sent to orbit, and by other reports as the weight above the accompanying rocket casing. Still others narrow the definition to the specific weight of instrumentation carried in a space vehicle. Illustrative is the variety of numbers associated with an Apollo Moon flight. The typical range of numbers are 136.000 kilograms in Earth orbit, 45.400 kilograms to the vicinity of the Moon, 5.440 kilograms returned to Earth, for a crew, some rocks, and film with an approximate weight of perhaps 400 kilograms.

The amount of payload carried by a given rocket is subject to division of weight carrying capacity between fuel to attain a given velocity in order to reach certain altitudes or inclinations, and the useful payload of the vehicle structure and its instrumentation or passengers. A given rocket will place the largest amount of weight in orbit by being fired due east from an equatorial launch site, because the rotational speed of the Earth is added to the rocket speed. All launches from sites closer to the poles or at higher inclinations if posigrade put up less payload. The use of retrograde orbits at any inclination exacts a carrying penalty by working against the rotation of the Earth.

Being mindful of these several qualifications, perhaps the most useful kind of comparison is to estimate the weights of payload which could be put into a low circular orbit, which reflects in a sense the potential payload capacity of each launch, even if in a particular case payload was traded for more fuel to send the lighter payload to higher orbit or to escape. We are handicapped in compiling such statistics related to total weight by other problems. For some vehicles, we do not have definitive information on their lifting capabilities (see the discussion which follows on each Soviet vehicle). Further, even when we know something about vehicles, such as those of the United States, there are constant technical changes being made and the precise characteristics of even the seemingly known vehicles may not really be known to the outsider. Most striking are the kinds of changes which have occurred in the Thor Delta family whose capacity ranged from a few hundred kilograms in the early days to a spread today up to thousands of kilograms, depending upon the length of main tank, and the number of solid-fuel strap-ons.

Table 1–5 which follows is offered with some resitation because it is so approximate, but it probably is generally indicative of trends. It assumes an approximate average capacity for each launch vehicle used, and applies this to the number of launches each year from each country. The table has not been further refined to convert the comparisons to a uniform eastward equatorial launch; rather, it accepts as the average the site of Tyuratam as the best Soviet site at about 45.6 degrees north latitude, and Cape Canaveral as the best U.S. site at about 28.5

degrees north latitude. Hence the table is not a measure of any actual weight of payload, whatever that definition. It represents some kind of a normalized maximum carrying capacity of rockets to place spacecraft in an orbit of about 185 or 200 kilometers above the Earth, firing due east from the named launch sites or their other national equivalents. The table divides the U.S. and Soviet payloads between small and medium launch vehicles and those of very large capacity, because the latter so influence the totals.

Others have tried to estimate the actual weight of Soviet payloads by use of the small number of data points made available. The most ambitious and recent of these calculations is that by Anthony Kenden of the United Kingdom.[1] Kenden took as a starting point a figure mentioned by the Soviet Chief Designer of Rocket Engines, Valentin Glushko, who cited by July 1, 1973 a Soviet total of 742 satellites weighing 2,233 metric tons, and 41 more weighing 110 tons which reached escape velocity. Kenden then examined lifting capacities quoted by the TRW Space Log, previous studies of the present writer, and those of the tables published by the Royal Aircraft Establishment. He examined in some detail the flights for which there are Soviet published weight figures, those whose weights are fairly readily estimatable, and finally those that are more obscure. By looking at each class of launch vehicle and each type of mission, Kenden builds numbers which provide a reasonably good fit with the figure from Glushko. His effort is generally satisfying, although there is one minor flaw. He assumes that certain figures published in the TRW Space Log have been estimated by them on the basis of optical data and decay rates. The figures in question were supplied by the present writer to TRW, and he in turn obtained them from the publications of the RAE in Great Britain. Hence, although they may be the best numbers obtainable, many of them essentially are estimates made by J. A. Pilkington, and similarities from one source to another are not signs of confirmation but of use of the same original source.

[1] Kenden, Anthony. An analysis of the masses of Russian spacecraft. Spaceflight, London, August/September 1975, pp. 289–297, and 344.

TABLE 1-5—WORLD TABLE OF PAYLOAD WEIGHT TO ORBIT OR BEYOND

[Based on nominal lift capacity in kilograms of launch vehicles to 185-200 kilometer circular orbit]

Year	U.S.S.R.			United States			France	Japan	Italy	China	United Kingdom	Australia	Total
	G-1-e	Other	Total	Saturn V	Other	Total							
1957		1, 016	1, 016										1, 016
1958		1, 361	1, 361		1, 451	1, 451							2, 812
1959		14, 152	14, 152		5, 171	5, 171							19, 323
1960		14, 152	14, 152		11, 725	11, 725							25, 877
1961		33, 112	33, 112		32, 455	32, 455							65, 567
1962		77, 337	77, 337		60, 668	60, 668							138, 005
1963		67, 631	67, 631		43, 182	43, 182							110, 813
1964		123, 037	123, 037		104, 213	104, 213							227, 250
1965		234, 190	234, 190		147, 894	147, 894	54						382, 138
1966		228, 837	228, 837		177, 445	177, 445	54						406, 336
1967		326, 178	326, 178	129, 274	122, 493	251, 767	109		159			68	578, 281
1968		398, 163	398, 163	258, 547	126, 484	385, 031							783, 194
1969		392, 176	392, 176	517, 095	80, 331	597, 426							989, 602
1970		405, 012	405, 012	129, 274	62, 754	192, 028	399	136		299			597, 874
1971		433, 294	433, 294	258, 547	77, 746	336, 293	200	299	159	299	118		770, 662
1972		343, 120	343, 120	258, 547	87, 929	346, 476		150					689, 746
1973		522, 515	522, 515	129, 274	143, 358	272, 632							795, 147
1974		475, 614	475, 614		69, 672	69, 672		150	318				545, 754
1975		471, 572	471, 572		120, 338	120, 338	272	204		4, 763			597, 149
Total		4, 562, 469	4, 562, 469	1, 680, 558	1, 475, 309	3, 155, 867	1, 088	939	636	5, 361	118	68	7, 726, 546

NOTES

1. There is no way to build a complete and accurate record of exact payload weights carried to orbit by launch vehicles in the absence of official disclosures which are largely lacking, and in the absence of uniform definitions of what is "payload".

2. By taking the occasional data points which are available for each known type of launch, vehicle, its general capacity can be estimated.

3. Comparability is also made difficult in that the latitude of the launch site and the launch azimuth affect the capacity of any given launch vehicle to lift weight to orbit.

4. The weight of payload carried by a given rocket tends to be inversely related to the terminal velocity imparted to it by the launch vehicle. Higher velocity to attain higher orbits may be acquired by trading off payload for more fuel, or cutting payload weight with the same amount of fuel.

5. An indirect and approximate measure of resource commitment to successful flights can be obtained by assuming for each flight that the approximate weight it might have carried to a 185-200 kilometer circular orbit due east from the most southerly launch site of the launching nation is what each use of that launch vehicle produced.

6. Because the total U.S. weight record has been so influenced by use of the Saturn V, that portion of the U.S. record is shown separately, and a similar column is provided for the corresponding Soviet G-1-e vehicle when and if it is used.

7. All the data must be regarded as only generally indicative, as it is not practical to adjust each launch for variations in the subtypes of each major launch vehicle. For example, the Thor Delta in a given year may fly with varying numbers of strap-on solid boosters; an average figure has been applied to Thor Deltas without strap-ons and those with. Similar averages have been applied to other types of launch vehicles.

SOURCES: The number of flights and launch vehicles for each have been derived from Appendix A for the Soviet flights; from the annual President's reports to Congress on aeronautical and space activities for the U.S. flights, and from the trade press for flights of other nations. The weights applied to these statistics have been estimated as described in the notes and in the text of the main report.

II. Launch Sites in the Soviet Union

The Soviet Union has three collections of space launch pads, just as does the United States. Curiously, even the functions of these three locations have a similarity, which will be detailed in the sections to follow.

A. TYURATAM

The largest and most versatile of the Soviet launch sites is near the rail stop village of Tyuratam in Kazakhstan at about 45.6° N. latitude, 63.4° E. longitude. The Russians call it the Baykonur Cosmodrome, although it is about 370 kilometers southwest of the station stop of that name on quite a different railway line. It originally may have been thought that by giving contradictory information about the cosmodrome, the Russians would maintain some element of doubt in the Western world, since the town of Baykonur is on the correct ground trace of the early Soviet flights which were at 65° inclination. To this day the Russians pinpoint the launch pad for manned flights as being at 47.3° N. and 65.5° E. which is patently false in light of conclusive public evidence of initial revolution ground traces and known launch times. Presumably based upon Soviet data, the NASA press kit for the Apollo-Soyuz Test Project lists the launch site as being at 47.8° N. and 66° E. This does not square with NASA Landsat photographs and the visits and descriptions supplied by NASA visitors to this launch site.[2]

Tyuratam was first accurately placed in public announcements by the optical studies of Professor Tadao Takenouchi in December 1957 following his observations of Sputnik 1 and 2.[3] The American trade press continued for some years to report the launch site as being in European Russia, until the Russians themselves announced it was in Kazakhstan (albeit at false coordinates, at the time of the Gagarin flight in 1961.)

Tyuratam was the site from which the first Soviet ICBM's were fired, all the early Sputniks, all manned flights, all lunar and planetary flights, the earlier communications satellites, all the fractional orbit bombardment system (FOBS) and military inspector flights. It is also the area from which all heavy payloads put up by the Proton "D" type launch vehicle. Presumably when the largest Soviet launch vehicle is brought into use, the same site selection reasons will recommend Tyuratam as the logical place for its launch.

In effect, Tyuratam is the Kennedy Space Center (Eastern Test Range) of the Soviet space program.

The first good look at the immediate launch site of the standard launch vehicle was provided by a 1967 movie giving an historical review of the Soviet program during the previous ten years. Those fairly sweeping panoramic views fit consistently with the carefully cropped or pointed views which had been released piecemeal in previous years. Earlier the Russians had disclosed that the historical marker for Sputnik 1 was beside the pad used for manned launches, one more factor confirming the long term use of both the same pad and the same first stage for missions from Sputnik 1 through Soyuz 19, the Apollo-Soyuz

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[2] Aviation Week, New York, January 14, 1974, pp. 12–13, pictures.

[3] Takenouchi, Tadao: A launch site in the Kizil Kum Desert? Kagaku Asahi, Tokyo, February 1958, pp. 40–48 (in Japanese); reported earlier in press dispatches.

Test Project (ASTP) flight. For a long time no outsider could get to the launch site. President De Gaulle was taken there in June 1966 to see the launch of the first acknowledged weather satellite (Kosmos 122), accompanied only by his personal physician. In 1970, President Pompidou saw the launch of a military observation satellite (Kosmos 368) which carried a supplemental scientific payload. Finally, in connection with the upcoming ASTP flight, three parties of American astronauts and technicians were flown in at night, put up in a hotel, driven to the launch pad, and then were returned to their hotel for another night flight out.

In the meantime, low resolution pictures made public by NASA routinely to anyone interested showed that the Landsat 1 views of the Tyuratam area were covered with roads, railway tracks, and other signs of human activities including almost certainly assembly buildings and launch pads which spread over a distance of about 135 by 90 kilometers or more. Also, the NASA people flying at night saw a scattering of electric lights from their aircraft that spread over distances of about this amount. At the day of the launch, the American ambassador, the science attache, and Willis Shapley of NASA headquarters were flown there in daylight hours for the launch, but did not see too much from the air. People did report that the little railway stop of Tyuratam these days, is completely overwhelmed by the adjacent city of Leninsk, of perhaps 50,000 people. This city has not been shown in public Soviet atlases, and seems to owe its existence to the growing space activity. With launch pads for many different launch vehicles widely scattered over the area, it is not possible to speak of a single closely defined latitude and longitude as defining the site, or to know what all the launch facilities look like. The original "A" class standard launch vehicle is carried horizontally on railway flat cars to the launch pad, tilted up, to sit on a stand over a large flame deflector pit. The base of the rocket in the upright position is well below the level of the railways tracks which deliver the rocket. There is a many-platformed service tower which is tilted away from the vehicle some time before launch, and shorter supports for the first stage which retract away after ignition when thrust reaches a certain level. Tall adjacent light-weight structures are described as carrying lightning rods to minimize electrical interference with the launch equipment and vehicle, and perhaps to carry television or motion picture equipment.

One gains the impression that tracking and guidance of Soviet space vehicles during the launch phase involve fixed radio, radar, and/or optical stations down range. This is because repetitive flights of a given launch vehicle tend to be flown at almost exactly the same orbital inclinations. To achieve the right azimuth for launch, the whole vehicle assembly and platform are rotated to the required compass heading. When two very similar yet different flight inclinations are achieved using different launch vehicles and other evidence supports the judgment, one receives the impression the difference in launch vehicle is also matched by using a different launch pad, and in order to fly the right "slot" in relation to the guidance points down range, the resulting orbit has a slightly different inclination.

Pictures in movies as well as the visits of NASA people show that the assembly of vehicles and the attachment of payloads occurs in special assembly buildings. Checkout of spacecraft is done in the ver-

tical position. Mating of spacecraft and launch vehicles is done horizontally.

Although only one launch pad in a vast cosmodrome has been opened to limited inspection, the Landsat pictures of the whole area confirm the general impression that this is open steppe country, relatively flat and only slightly rolling. There is no basis to the rumors of the early days that Soviet launches were conducted by winged, recoverable booster stages which ran on a track up a mountain side before becoming airborne.

Other Landsat pictures suggest there is a general area in which spent first stages impact on the steppe, and informally Russians in the program have suggested they are able to salvage for reuse some components from this "bone yard".[4]

A Soviet account of the Baykonur Cosmodrome described the assembly-test building used for the Soyuz. The building is called the MIK (Montazhno Ispytatel'nyy Korpus). The article said that a Soyuz is first given a full checkout in the MIK, and then again on the pad. In the MIK, the separate modules are tested in vacuum chambers, including the firing of maneuvering engines. After the individual modules are tested, they are assembled to create the whole vehicle and returned to the vacuum chamber for further checkout. Then they are also placed in an anechoic chamber to test the radio compatibility of the assembled ship with its communications systems.[5]

Another account of the Tyuratam complex was carried by *Spaceflight*. Leninsk was identified as the long-referenced "Rocket City" of Soviet accounts, about 2,090 kilometers southeast of Moscow on the main Moscow-Tashkent railway line, with Tyuratam the original village railway stop. The area was described as rolling but mostly flat country, with complex irrigation systems and some tall trees planted. The climate is very extreme summer and winter. It is said to be about 32 kilometers from Leninsk to the ASTP launch pad, and about 1.6 kilometers from the MIK to the pad, using the standard Soviet 5 foot gauge railway track to join the two points. The second pad for the ASTP backup was supposedly another 32 kilometers away. The same account said there is a test building for the G–1–e rocket and a gantry 122 meters tall for full assembly testing of the G–1–e.[6]

B. PLESETSK

The second of the Soviet launch sites is near the town of Plesetsk on the railway from Moscow to Archangel at about 62.8° N. latitude, 40.1° E. longitude in European Russia. This site has never been specifically acknowledged. It is finding increasingly heavy use, primarily as an operational site, in contrast to the often experimental or specialized nature of the Tyuratam flights.

Plesetsk is in effect the Vandenberg Air Force Base (Western Test Range) of the Soviet Union. From here are launched many of the navigation satellites, the weather satellites, and the majority of the military satellites for a wide range of purposes. Now also, most of the Molniya class inclined orbit communications satellites which previous-

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[4] Aviation Week, New York, February 18, 1974, p. 17, pictures of drop area.
[5] Pravda, Moscow, May 25, 1975, pp. 1, 2.
[6] Spaceflight, London, 11 October 1975, p. 368.

ly were launched from Tyuratam are also launched from Plesetsk. With its northern location, Plesetsk is used for missions which require coverage of extensive parts of Earth, since even flights launched due east for maximum payload capacity cover most of the inhabited Earth.

Plesetsk had been discussed in the Western press as a missile launching area. Its later space role presumably was known to Western governments, but the first public disclosure of this space cosmodrome came from the Kettering Grammar School in England. Geoffrey E. Perry published the first clue in April 1966 shortly after the first space launch in March.[7] He published the pinpointed location in November 1966 when flights at different inclinations had established a nodal point of crossing ground traces.[8] As additional kinds of missions were launched from the Plesetsk area, their patterns of orbital inclinations suggested launch pads scattered over a considerable geographic area. Landsat pictures confirmed to the public that Plesetsk was spread over tens of kilometers although not quite as large as the Baykonur Cosmodrome near Tyuratam.[9]

When weather conditions are just right, an occasional Plesetsk launch has been visible from Sweden and Finland, when the still firing rocket rises above the horizon. The closest the Soviet Government has come to acknowledging Plesetsk is to permit its use for cooperative Soviet Bloc payload launches, one of the first being Interkosmos 8 of 1972.

C. KAPUSTIN YAR

The third Soviet launch site is near Kapustin Yar on the Volga River below the city of Volgograd at about 48.4° N. latitude, 45.8° E. longitude, also in European Russia. Indirectly the site has been finally acknowledged by the Soviet Government, as some suborbital launches as referred to as coming from "Volgograd Station". The area has been used for a long time as a rocket test station. In the middle 1950's before the first Sputnik, *Aviation Week* magazine revealed the United States had a radar station in Turkey which used radar to follow missile and test rocket firings from this point.[10] Magazines of the period said that Soviet short and medium range missiles were launched southeastward from there toward the Kyzylkum Desert near the Aral Sea as the principal test range. In fact, this launch site was so well known that for several years after 1957, the American press assumed that it was used for the launch of the early Sputniks and Luna flights when in fact they came from the Tyuratam ICBM test center.

It was not until 1962 that payloads were placed in orbit from the Kapustin Yar site, using the smallest of the Soviet launch vehicles, and only in 1973 did they start space launches from Kapustin Yar which used the intermediate size of launch vehicle. All the "B" class small launch vehicles from there put payloads into an inclination of 48.4 to 49 degrees. All the intermediate "C" class vehicles put payloads into an inclination of about 50.7 degrees inclination.

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[7] Perry, G. E., Flight International, London, April 21, 1966, p. 670.
[8] Perry, G. E., Flight International, London, Nov. 10, 1966, p. 817.
[9] Aviation Week, New York, April 8, 1974, pp. 18–20.
[10] Aviation Week, New York, October 21, 1957, p. 26.

The combination of use of the smaller launch vehicles and the use of the site for launching vertical probes make this site seem to parallel a combination of the Wallops Island, Virginia station, and the White Sands, New Mexico test area. Some Western observers speculated that when the day came that the Soviet Government would ease its security rules sufficiently to open a launch site to outside visitors that Kapustin Yar was most likely to be the first to "go public". This view was encouraged when finally Soviet bloc scientists were permitted to go there in connection with the launch of Interkosmos flights which began in 1969.

Landsat pictures of the area show signs of activity over many kilometers, but not on the scale of Tyuratam or even Plesetsk.[11]

Sary Shagan, the anti-ballistic missile (ABM) test station to intercept rockets fired from Kapustin Yar, was also found in Landsat pictures.[12]

Table 1–6 which follows summarizes the known successful launches by site, worldwide, to provide a perspective on their relative levels of activity for orbital launch purposes. The figures do not reveal additional suborbital or missile launchings. The table reveals that Plesetsk has conducted more successful orbital launches than any other base in the world with Vandenberg and Tyuratam running neck and neck, and Cape Canaveral a poor fourth.

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[11] Aviation Week, New York, December 1, 1975, pp. 18–19.
[12] Aviation Week, New York, November 25, 1974, pp. 20–21.

TABLE 1-6.—NUMBER OF SUCCESSFUL ORBITAL AND ESCAPE LAUNCHES BY SITE AND BY YEAR

Launch Site	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Total
Plesetsk, Russia										6	26	30	37	48	53	52	61	55	62	430
Tyuratam, Kazakhstan	2	1	3	3	6	13	13	23	41	31	33	36	30	27	29	20	23	25	26	385
Vandenberg, California			5	7	16	34	27	38	36	43	35	30	22	17	18	19	10	13	12	382
Cape Canaveral, Florida		5	5	9	11	17	10	16	24	29	22	14	18	10	10	10	13	9	15	247
Kapustin Yar, Russia						7	4	7	7	7	7	8	4	5	1	2	2	1	1	63
Wallops Island, Virginia					2	1	1	3	3	1		1		1	2	1				16
Indian Ocean Platform, Kenya											1			1	2	1		2	1	8
Uchinoura, Japan														1	2	1		1	2	7
Kourou, Guyane														2	1				3	6
Shuang Cheng Tzu, China														1	1				3	5
Hammaguir, Algeria									1	1	2									4
Woomera, Australia											1				1					2
World total	2	6	13	19	35	72	55	87	112	118	127	119	111	113	120	106	109	106	125	1,555

NOTES

1. The definition of "successful" launch is as used elsewhere in tables of this report—the attainment of orbit, not the functioning of the payload.

2. Launch sites of space flights are only occasionally announced; hence many launches have been placed by comparing the flight inclination to the Equator with other flights of known origin. All escape missions to date have come either from Cape Canaveral/Merritt Island or from Tyuratam, which made those assignments possible. In cases where the orbital inclination alone might leave in doubt which of two sites in a given country was used, then the ground trace on the zero revolution has made it possible to identify the launch site; data on such ground traces enter the public domain most often from United Kingdom sources.

SOURCES: Appendix A of this report for Soviet launches. The annual President's report to Congress on aeronautical and space activities for U.S. launches. The Western trade press for accounts of launches from other countries.

III. Soviet Launch Vehicles

In the Soviet Union as well as in the United States, the development of military long range missiles was the essential source of most of the space launch vehicles until such time as space needs for larger capacity rockets began to exceed missile capabilities.

There was one difference, however. The United States started its civilian space program with a non-military launch vehicle, the Vanguard, assembled for the International Geophysical Year (IGY) by a team directed by the Naval Research Laboratory. This country moved step by step to use of the modest-sized Redstone, and then to intermediate range missiles, the Jupiter and the Thor, before applying any ICBM's to orbital flights. Its small, solid-fuel Scout, like Vanguard, was not evolved from a military missile.

By contrast, the Soviet Union from the outset took its original ICBM and applied it to space work for the flights from 1957 on, and still uses this vehicle, although now with improved final stage or stages. Only after some years did the Soviet Union move down in size to use of medium-range and intermediate-range missiles as first stages for space launch vehicles. Also, an improved Soviet ICBM has been brought into the stable of space launch vehicles, but to date has been reserved exclusively for limited types of military space payloads.

When both countries needed to exceed the capability of existing military missile first stages, they moved to create launch vehicles exclusively dedicated to space launches. In this country, these were the Saturn family, plus the hybrid Titan III vehicles which combined a modified military missile with large solid-fuel strap-on boosters. In the Soviet Union, the first larger vehicle was the Proton or "D" family, and we believe, a new larger vehicle in the Saturn V class, the "G" family, which has not yet flown successfully.

TABLE 1-7.—NUMBER OF SUCCESSFUL LAUNCHES TO EARTH ORBIT AND BEYOND BY BASIC FIRST STAGE BY YEAR

Launch Vehicle	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Total
"A", SS–6 Sapwood (U.S.S.R. missile)	2	1	3	3	6	13	13	22	33	34	36	41	43	43	40	47	53	49	58	540
Thor (U.S.A. missile)			6	14	18	35	25	29	31	22	28	19	21	16	13	11	6	9	14	317
Atlas (U.S.A. missile)		1		1	8	14	9	16	14	32	14	7	5	2	4	6	4	2	3	142
"B" SS–4 Sandal (U.S.S.R. missile)						7	4	7	7	7	13	16	14	18	12	12	10	6	5	138
"C" SS–5 Skean (U.S.S.R. missile)								1	6		4	6	6	10	19	13	15	17	18	115
Titan (U.S.A. missile)								2	10	10	9	10	8	7	8	7	8	7	9	95
Scout (U.S.A.)					2	3	4	7	5	8	6	5	2	3	5	5	1	6	2	64
"F" SS–9 Scarp (U.S.S.R. missile)										2	11	7	3	6	6	1	1	3	4	44
"D" Proton (U.S.S.R.)									2	1	2	4	4	4	6	1	7	6	4	41
Saturn V (U.S.A.)											1	2	4	1	2	2	1			13
Saturn I (U.S.A.)								3	3	1		2					3		1	13
Diamant B (France)														2	1				3	6
Mu (Japan)															2	1		1	1	5
Redstone (U.S.A. missile)		3									1									4
Jupiter (U.S.A. missile)			2	1	1															4
Diamant (France)									1	1	2									4
China B (China)																			3	3
Vanguard (U.S.A.)		1	2																	3
China A (China)														1	1					2
Lambda (Japan)														1						1
Black Arrow (United Kingdom)															1					1
Total	2	6	13	19	35	72	55	87	112	118	127	119	110	114	120	106	109	106	125	1,555

NOTES

1. To keep the table to manageable size, flights have been grouped according to basic first stages, and not further subdivided to reflect each model and modification or each upper stage combination. For example, only the Thor is listed, not Thor Able, Thor Able Star, Thor Delta, Thor Agena, Thor Burner II, etc.

2. The national origin of each vehicle and whether it was originally a military missile is shown, without regard to the nationality of the launching country or launch site for a particular flight.

3. The Soviet letter designator is that used in this report; the SS- designator is that used by the U.S. Department of Defense for particular Soviet vehicles in their missile guise if any; the code name beginning with "S" is that used by NATO for a particular missile. The trade press is also used an "SL" designation plus a number for particular launch vehicle stage combinations, but these supposed Department of Defense designations have not been put into the public domain and confirmed, so have not been used.

4. Vehicles have been identified by combining information on those few flights where such data have been released in the Soviet case with data on other flights exhibiting the same characteristics.

SOURCES: Soviet data are derived from Appendix A of this report. U.S. data are from the annual President's reports to Congress on aeronautical and space activities. Data on other countries have been reported in the Western trade press.

Table 1–7 summarizes the successful flights of basic classes of launch vehicles over the years by all countries, providing a perspective on their relative frequency of use. This table has deliberately been kept simple, and it does not reflect the great number of upper stages used with the basic vehicles.

The table shows that the Soviet original ICBM, Sapwood, or "A" remains the most used launch vehicle in the world, followed by the U.S. Thor. Use of the Sandal or "B" began in 1962. The Skean or "C" came into use in 1964. The Scarp or "F" after its introduction in 1966 seems to have peaked early and is used only occasionally now. The Proton or "D" as a bigger vehicle is used less frequently, but its applications are growing. We are still waiting for a first successful flight of the "G" very large vehicle, so it does not appear in this table. *Aviation Week* and other publications claim there have been three flight failures of the "G" vehicle since a first attempt in 1969. Even the "D" vehicle seems to have had many troubles in development.[13]

The Soviet Union does not name or even identify by appearance and capacity many of its launch vehicles, giving reasons of military security. Only after many years have pictures of some been released or models put on display. It is a satisfaction that these pictures and models when made available are consistent with the previously derived inferential analyses based upon the performance of these vehicles and the few facts disclosed by the Soviet Government.

The original Soviet ICBM which was brought into both missile and space use in 1957 was put on public display in 1967 under the label Vostok. The same launch vehicle but with a longer upper stage is used for Soyuz. Neither label is sufficiently descriptive for the purposes of this study, as this original first stage and the two kinds of upper stages are used for many different missions. Likewise, the smallest of the Soviet space orbital launchers is now on display labeled Kosmos. This is not sufficiently descriptive either because the Kosmos name has been applied to payloads launched by all five basic first stages. It may be worth emphasizing that in the absence of any comprehensive and consistent public use by the Soviet government of a nomenclature system, all those in general use in the West have been invented in the West. In the early days of orbital flight a great variety of names of space vehicles purportedly of Soviet origin appeared in magazines, but they seem to have had no more basis than the fanciful track up the mountain side for the winged launchers which in fact never existed.

Gradually over a period of years, Soviet missiles of the surface-to-surface type were assigned numbers with the prefix SS by the U.S. military services, and as these missiles were better and better defined, their designators and approximate characteristics were made available to the trade press or showed up in congressional testimony. Thus the SS–4, SS–5, SS–6 . . . Some of these missiles such as the SS–7 and SS–11 achieved a prominent place in the Soviet arsenal without being clearly seen by the Western public, and they were not used as space launchers. When missiles were seen to the extent their configurations were recognizable by the military branches of the NATO powers, code

[13] Alsop, Stewart. Salt and Apollo 13. Newsweek, New York. April 27, 1970, p. 112. He described a large number of failures of this vehicle.

names such as Sandal, Skean, Sapwood . . . were assigned, and these also in time reached the trade press. Military authorities in the West seem also to have created a nomenclature system for space launch vehicles, whether of military missile or other origin, and these carry the prefix SL. But an authenticated list has not been made public, so cannot be used here across the board. Some years ago in the TRW *Space Log* in the absence of anything better a system was devised which is being used in this report because its use has spread throughout much of the Western world, and it meets at least minimum needs. The basic scheme is to assign a capital letter to each basic first stage, and then to use a number for the principal upper stage of the particular launch vehicle, and a second number if the earlier upper stage is replaced. A final stage is indicated by a small letter generally indicative of its capability such as e—escape, m—maneuvering, r—reentry, and h—higher performance.

As subsequent discussion will show, even though the Soviet Union has not disclosed an overall nomeclature system for its launching vehicles, it has identified some of the individual rocket engines, such as RD–107, RD–108, RD–119 . . . , which will be discussed in later parts of this chapter.

Table 1–8 is a summary of the characteristics of Soviet launch vehicles. Because of Soviet secrecy, it must be considered as highly provisional. This is especially true when irreconcilable differences exist in partial Soviet data made public, and when Western observers have not seen pictures of some models and disagree as to their possible performance. With this warning about uncertainties, perhaps the table at least gives some notion of the scope of launch vehicles, the relatively modest number of kinds, and about what their dimensions, power plants, fuels, and thrust approximate.

Table 1–9 summarizes data for each known rocket type as to the number of kilograms which can be sent to different orbits, and trends over the years as these vehicles have evolved. It suffers the same uncertainties as other tables where the Soviet Government released only partial information, so must be considered provisional and subject to revision. However, it is at least generally indicative of what the lift capacity of each principal rocket is.

TABLE 1-8.—SOVIET LAUNCH VEHICLE CHARACTERISTICS

Vehicle Segments	Length	Diameter	Main Engines	Main Nozzles	Engine Designator	Propellants	Chamber Pressure (Atmos)	I_{sp}	Total Thrust	Typical Payloads
A										
core	28	2.95	1	4	RD-108	Kerosene-LOX	52	315	96	Sputnik 1-3.
4 boosters	19	3	4	16	RD-107	Kerosene-LOX	60	314	102	
shroud	3.87	2.58								
overall	31.87	10.3	5	20					504	
A-1										
core	28	2.95	1	4	RD-108	Kerosene-LOX	52	315	96	Luna 1-3.
4 boosters	19	3	4	16	RD-107	Kerosene-LOX	60	314	408	
upper stage	3.1	2.58	1	1						
shroud	2.58	2.58								
overall	33.68	10.3	6	21					(600)	
A-1										
core	28	2.95	1	4	RD-108	Kerosene-LOX	52	315	96	Vostok, Kosmos, Meteor.
4 boosters	19	3	4	16	RD-107	Kerosene-LOX	60	314	408	
upper stage	3.1	2.58	1	1						
shroud	6.9	2.84								
overall	38	10.3	6	21					(600)	
A-2										
core	28	2.95	1	4	RD-108	Kerosene-LOX	52	315	96	Voskhod, Kosmos.
4 boosters	19	3	4	16	RD-107	Kerosene-LOX	60	314	408	
upper stage	8	2.58	1	4					30	
shroud	6.9	2.84								
overall	42.9	10.3	6(7)	24				534	(650)	
A-2										
core	28	2.95	1	4	RD-108	Kerosene-LOX	52	315	96	Soyuz.
4 boosters	19	3	4	16	RD-107	Kerosene-LOX	60	314	408	
upper stage	8	2.58	1	4					30	
shroud	13.3	3.04								
overall	49.3	10.3	6	24					534	
A-2-e										
core	28	2.95	1	4	RD-108	Kerosene-LOX	52	315	96	Luna 4-14, Zond 1-3, Venera 1-8, Mars 1, Molniya, Kosmos.
4 boosters	19	3	4	16	RD-107	Kerosene-LOX	60	314	408	
upper stage	8	2.58	1	4					30	
escape stage	2	2	1	1						
shroud	6.9	2.84								
overall	42.9	10.3	7	25						

TABLE 1-8. SOVIET LAUNCH VEHICLE CHARACTERISTICS—Continued

Vehicle Segments	Length	Diameter	Main Engines	Main Nozzles	Engine Designator	Propellants	Chamber Pressure (Atmos)	I_{sp}	Total Thrust	Typical Payloads
B-1										
first stage	20.3	1.65	1	4	RD-214	Nitric acid, refined product of kerosene	45	264	72	Kosmos, Interkosmos.
second stage	8.5	1.65	1	1	RD-119	UDMH,	80	352	11	
shroud	3.3	1.65								
overall	32.1	1.65	2	5					83	
C-1										
first stage	19.8	2.5	1						118?	Kosmos, Interkosmos.
second stage	8.4	2.5	1							Oreol, Aryabhata.
shroud	3.4	2.5								
overall	31.6	2.5								
D-1										
core		4			RD-253		"100's"			Salyut (Proton).
6 boosters		4					"100's"			Kosmos.
second stage		4					"100's"			
shroud		4								
overall		13								
D-1-e										
core		4			RD-253		"100's"			Zond 4-8, Luna 15–
6 boosters		4					"100's"			Mars 2–
second stage		4					"100's"			Venera 9–
escape stage		4								Molniya 1S
shroud		4								Kosmos
overall		13								
F-1-m or r										
first stage	20.7	3	1	6						Kosmos
second stage		3	1							
third stage			1							
shroud										
overall										
G-1-e										
first stage										
second stage										
third stage										
shroud										
overall										
Specific use not named					RD-119	Nitric acid-UDMH	75	293	90	Upper stages of D or F vehicles

NOTES

1. This table should be used with extreme caution. It is virtually impossible to get certain figures on the dimensions of stages on Soviet launch vehicles; the U.S.S.R. has to date revealed dimensions only for the A-1, A-2, and B-1 vehicles.

2. The Western trade press can only examine photographs of the few Soviet vehicles which have been pictured and try to relate their size comparatively to sizes of men or known equipment appearing in the same picture. This has resulted in a range of figures among sources for almost all vehicles.

3. The C-1 was not shown in a public photograph until 1975, and its dimensions cannot be scaled to a certainty from the pictures. Lengths used here have been estimated from the most commonly reported diameters of the SS-5 Skeen missile.

4. The D-1 has had only the upper portion of its basic core stage and tips of strap-ons shown in a photograph which also included the upper stage used for a Salyut launch. Other dimensions have been estimated by assuming the same technology as applies to the A class vehicles, scaled up to three times the volume.

5. The F-1 classes of vehicles have not been pictured, although the SS-9 Scarp lower stages have been seen with a variety of Western guesses as to how long it is; an average of these has been taken.

6. The G-1 classes of vehicles have not been pictured, and lengths have been estimated only by assuming the same technology as the A class vehicles and scaling up 12-fold from that vehicle.

7. There are uncertainties even about variants of the A class vehicles. For flights other than Vostok and Soyuz, all other dimensions have been scaled from photographs if available.

8. In certain cases, the number of rocket engines and their total thrust is put in parens; these are numbers officially released by the Russians, but not borne out by later photographs or models. For example, the Voskhod launch vehicle was credited with 7 engines, while only 6 are used for the Soyuz which employs the same launch vehicle. The thrust of Vostok was given as 600 metric tons and of Voskhod as 650 metric tons; yet the thrust of the Soyuz launcher adds up to only 534 metric tons. The original Soviet data implied by subtraction that the lunar upper stage had a thrust of 90 metric tons (subtracting five other engines of 102 metric tons each); and that the planetary upper stage(s) had a thrust of 140 metric tons (subtracting five other engines of 102 metric tons each). These high numbers would have given very high G loads in acceleration. At the time of Apollo-Soyuz, the interplanetary upper stage was revealed to have a thrust of 30 metric tons, not 140 metric tons. The lunar upper stage would be even less. Also, at the time of the Soyuz, the core stage thrust was listed as 96 metric tons, not 102 metric tons as previously reported by the Russians.

9. Where data on engines are given with designators, chamber pressures, I_{sp} (specific impulse in pounds of thrust per pound of propellant per second), and total vacuum thrust, these are as announced by the U.S.S.R.

10. Even the dimensional data on the Soviet A and B class vehicles show some variations between Soviet releases of data and models put on display.

SOURCES: See particularly Aviatsiya i Kosmonavtika No. 11, 1967, pp. 34–35, and Ibid. No. 12, 1967, pp. 33–37; also, Vestnik, Akademii Nauk, No. 11, 1967; and the book by A. A. Blagonravov et. al.: U.S.S.R. Achievements in Space Research (First Decade in Space 1957–1967), published by Nauka, Moscow, 1968, 557 pp. The photographs or drawings have appeared over a period of years in Aviation Week, Interavia, Flight International, the New Scientist, Spaceflight, Space World, and in Norman L. Baker: Soviet Space Log 1957–67, Space Publications Inc., Washington, 1967, 59 pp. Also see drawings by G. Harry Stine in Analog and American Aircraft Modeler, and in Björn Bergqvist, Vostoks bärfarkost, Teknist Tisskrift, (Swedish), 1968 H2, and other drawings by Maarten Houtman in Spaceview, Amsterdam, and by Peter Smolders in Dutch and English publications. More recently, detailed dimensions of the A-2 appeared in the Soviet press kit for the Apollo-Soyuz mission. David R. Woods in January 1976 in correspondence made estimates of the dimensions and thrust of the C-1 which differ slightly from those of the table.

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TABLE 1-9 — SOVIET LAUNCH VEHICLE LIFTING CAPABILITIES

Period	88	89	90	92	95	96	100	103	105	109	115	216	720	1,440	5,660			
Altitude	200	250	300	400	550	600	750	900	1,000	1,200	1,455	5,500	19,000	35,850	100,000	Lunar	Venus	Mars
Vehicle and year:																		
A-1:																		
1960		4,250	4,000													400		
1965	4,750	4,500	4,250															
1970	5,000	4,750	4,500			2,200												
1975						2,825												
A-2:																		
1960		5,250	5,000															
1965		5,500	5,250															
1970		5,750	5,500	5,300	5,085		4,520	4,238	4,100									
1975		6,000	5,750		5,335		4,770	4,500	4,350									
A-2-e:																		
1960			6,500													1,422	644	600
1965			6,750													1,640	960	890
1970	7,500	7,250	7,000										1,000		845	1,750	1,180	
1975													1,250					
B-1:																		
1965			375	355	325	308	290	275	260									
1970	420	410	400	380	350	333	315	300	285									
1975			425	405	375	358	340	325	310									
C-1:																		
1965					875	775		725	700									
1970	1,050	1,030	1,010	990	900	800		750	725	650	500							
1975					925	825		775	750	675	525							
D-1:																		
1965				12,200														
1970	22,500	18,600	18,000	17,000	15,500				13,000							6,125		
1975																		
D-1-e:																		
1965																		
1970														2,880		5,900	4,900	4,650
1975																6,600	5,900	5,600
F-1-m:																		
1965	4,350	4,100	4,000															
1970	4,536	4,310	4,200	4,000	3,600	3,300		2,950	2,700	2,585								
1975	4,700	4,500	4,400	4,200	3,800	3,500		3,150	2,900									
G-1-e:																		
1970																31,750		
1975																		

NOTES

1. The same extreme caution should be used in relying on this table as was required in Table 1–8. Real data are far too incomplete and many assumptions have to be made to develop the approximations shown here.

2. The table is built upon two major premises: first, that since payload lift capability is inverse to the altitude reached by the payload, data can be scaled from a few known data points; and second, that over a period of years product improvements in launch vehicles will lead to increases in their lift, capacity.

3. All the known weights of payloads have been put into the matrix of possible numbers by vehicle, by altitude, and by year. Then other numbers have been estimated by extrapolation or interpolation.

4. The five year intervals selected for a particular vehicle have been conditioned by the use or availability of that vehicle in the time frame shown.

5. Orbits are arbitrarily circularized; since many orbits are in fact eccentric, the approximate orbital period in minutes is also indicated to give a general indication of what the appropriate number would be. The periods and altitudes listed are those which come closest to reflecting actual Soviet choices of flights. In some cases there have been no flights at all approximating categories in the matrix, and they have not been filled in. For example, some vehicles have never been used for deep space flights.

6. The numbers listed are in kilograms.

7. The altitudes are in kilometers.

SOURCES: The primary source for the few solid numbers in the table have been Soviet TASS announcements, supplemented by estimates appearing in the RAE reports. The rest are calculated as explained in the notes above. Some of the trends over time through product improvements have been calculated by Phillip S. Clark and Anthony Kenden of the United Kingdom, and Saunders Kramer of the United States, with much the material appearing in articles or a series of letters to the editor in Spaceflight, London.

TABLE 1-10.—SOVIET LAUNCH VEHICLE UPPER STAGES AND CAPACITIES

Designations	Stage combinations	Orbital Stage(s) Diameter	Length	Empty weight	Payload maximum weight	Typical payloads
A	SS-6 Sapwood (2d stage)	2.95	28.0	6,000	2,000	Sputnik 1-3.
A-1	SS-6 Sapwood+Luna 3rd stage	2.58	3.1	1,440	5,000	Luna 1-3, Vostok, Kosmos, Meteor.
A-m	SS-6 Sapwood+maneuvering stage	2.0	5.0	700	3,000	Polet
A-1-m	SS-6 Sapwood+Luna 3rd stage	2.58	3.1	1,440		(suborbital).
	+maneuvering stage	2.0	5.0	700	4,750	Kosmos 102, 125.
A-2	SS-6 Sapwood+Venera 3rd stage	2.58	8.0	2,500	7,500	Kosmos, Voskhod, Soyuz.
A-2-e	SS-6 Sapwood+Venera 3rd stage	2.58	8.0	2,500		Prognoz, Komos, Mars 1, Zond 1-3.
	+probe rocket	2.0	2.5	1,100	7,500	Molniya, Luna 4-14, Venera 1-8.
A-2-m	SS-6 Sapwood+Venera 3rd stage	2.58	8.0	2,500		
	+maneuvering stage	2.0	5.0	700	7,500	Kosmos 379,398,434.
B-1	SS-4 Sandal+Kosmos 2d stage	1.65	8.5	1,500	450	Kosmos, Interkosmos.
C-1	SS-5 Skean+restartable 2d stage	2.5	8.4	2,000	1,100	Kosmos, Interkosmos, Oreol, Aryabhata.
D-1	Proton+3rd stage	4.0	12.0	4,000	22,500	Kosmos, Proton, Salyut.
D-1-e	Proton+3rd stage	4.0	12.0	4,000		
	+probe rocket	3.9	4.0	1,900	22,500	Luna 15-, Mars 2-, Venera 9-, Molniya 1-S.
D-1-m	Proton+3rd stage	4.0	12.0	4,000		
	+maneuvering stage	3.9	7.5	2,500	22,500	Kosmos 382.
F-l-m	SS-9 Scarp+3rd stage	2.5	6.0	1,500		
	+maneuvering stage	2.0	5.0	700	4,700	Kosmos Inspectors, Ocean Surveillance.
F-1-r	SS-9 Scarp+3rd stage	2.5	6.0	1,500		
	+retro stage	2.0	8.0	700	4,700	Kosmos FOBS.
G-1	+3rd stage				135,000	Possible orbital station.
G-1-e	+3rd stage					
	+probe rocket				135,000	Possible lunar flight.

NOTES

1. Moderate caution is required in relying on this table.
2. The vehicle classifications are those developed in the analysis contained in the main text of this report, with the probable stage combinations of each, generally described.
3. Most of the orbital stage (spent rocket casings of carrier rockets) dimensions and weights are those quoted in the RAE reports. However, because estimates based on optical and radar data are not precise, some stages that almost certainly have identical dimensions from one flight to the next are listed with different dimensions by the RAE, and so use of that data has been selective. The weight of the A-2-e probe rocket is estimated by the RAE at 440 kilograms; other studies by Woods suggest 1,100.
4. Purely on an intuitive basis, some assumptions have been made about the transferability of maneuvering stages from one launch vehicle series to another, and if there are later disclosures, these surmises may prove to be correct or may prove without foundation.

SOURCES: Primarily from RAE data, plus Soviet TASS releases for the A-2 and B-1 upper stages. The remainder of the dimensions and weights from inferences. Payload capacities were taken from data in Table 1-9, and typical missions from Appendix A. Correspondence with David R. Woods.

A. THE STANDARD LAUNCH VEHICLE SERIES ("A")

1. The Original Version—A

Some time in the early 1950's a large Soviet rocket engine was developed for use in connection with the first ICBM, and it may have been considered even at the outset for space work as well. The Russians designated this the RD–107. The engine burns kerosene and liquid oxygen, uses a single shaft turbine assembly to pump the oxidizer and fuel to four combustion chambers with exit nozzles and to two steering rockets. There are auxiliary systems to pump a hydrogen peroxide gas generator and to run a liquid nitrogen to nitrogen gas pressure supply. The engine operates at 60 atmospheres to produce a vacuum thrust of about 102 metric tons with an I_{sp} of 314 seconds. A variant of the same engine is called the RD–108, differing from its predecessor primarily in having four steering rockets instead of two, and its vacuum total thrust is 96 metric tons. The first ICBM which also became the launcher for Sputnik 1 was assembled by placing four long tapered tanks of roughly cylindrical shape around a sustainer core. Each of these strap-ons had an RD–107 engine and the central unit had an RD–108. All five units with their 20 main nozzles and 12 steering rockets are ignited on the pad, and as soon as thrust builds up to lift off the pad, the rocket rises. When the boost task is over, the four strap-ons fall away leaving the sustainer core to continue burning for a time.

The total assemblage creates a fairly graceful impression. The central sustainer core, 28 meters long, described from the ground up starts as a regular cylinder, then flares outward, and tapers back again, creating a hammer head effect. This peculiar shape was selected to blend with the four strap-ons which are modified elongated tapered cones. When all five units are strapped together, the result is a fluted pyramid effect with a maximum base diameter of 10.3 meters, including the four stubby fins.

This is the vehicle which the Russians claim first flew as their original ICBM from Tyuratam on August 3, 1957.[14] Then it was used for the launch of Sputnik 1 on October 4, 1957, and likewise for the next two Sputniks. During that period the rocket had no upper stage, so it was not used very efficiently for payload weight purposes. The entire sustainer core was placed in orbit on these occasions, and one of the blurred Western photographs taken of such a rocket tumbling in orbit definitely suggests its hammerhead shape which has since been revealed by the Russians. Judged by the weight of the last and heaviest of these payloads, the lifting capacity of the rocket was about 2 metric tons to low circular orbit. It is possible that the residual weight of the spent rocket casing was on the order of 6 metric tons.

With the announced weight of Sputnik 1 at under 84 kilograms, it is understandable why Western observers in that period postulated the use of a much smaller launch vehicle than the real one. When people rushed out of doors to see the passing of the first satellites, usually they were really viewing that 28 meter rocket casing, like a Pullman railway sleeper tumbling end over end, rather than the spherical Sputnik 1, 0.58 meters in diameter, or even Sputnik 3 which was 3.76 meters long. Sputnik 2 remained attached to its rocket.

[14] Moscow Radio, August 2, 1967 0800 GMT.

Some time later, when the United States launched the Project Score satellite in the same mode as Sputnik 2—namely, leaving the payload attached to the spent rocket casing—it injected the entire sustainer portion of the Atlas launch vehicle into orbit. The United States announced achievement of the world's heaviest satellite to date (3,969 kilograms). The useful payload was actually about 68 kilograms. This provoked Leonid Sedov of the Soviet Union into some testiness, when he pointed out that the total weight in orbit in connection with each of the three Sputnik launches had been in excess of the U.S. weight. The residual Soviet weight has been assumed to be about 6 metric tons, and the Sputnik 2 vehicle which like Score remained attached to the rocket body weighed 508 kilograms for a total combined weight of perhaps 6,508 kilograms.

2. Launch Vehicle with Lunar Upper Stage, A–1

Considering the lead times involved in developing space vehicles, it is likely that well before the time of Sputnik, the Russians were designing and building an upper stage to fit on their original model ICBM, and this raised its orbital capacity to over 4,700 kilograms, though its first use was for direct flights to the Moon with a net payload weight of about 400 kilograms.

This upper stage used for the Luna 1, 2 and 3 flights was the first Soviet spacecraft to be put on public display in replica. Mounted on top of the sustainer core by an open truss structure, it measures about 3.1 meters long and has a diameter of 2.58 meters. Strangely to this date the Russians have not announced the designator for the single nozzle engine or given its thrust. Its thrust should be on the order of 10 to 20 metric tons. We are left with a mystery in the Soviet accounts. They reported for some years that the total thrust of all the engines was 600 metric tons. Having then told us that the five engines of the core and boosters had a thrust of 102 metric tons each, by subtraction the upper stage thrust should have been 90 metric tons, which would have put a heavy G load on this stage when it fired. This is the amount of thrust of the Soviet RD–219 upper stage engine, but it has two nozzles, and the lunar stage engine has only one nozzle. When this rocket was used for the direct flights to the Moon, the lunar stage was accelerated to a speed sufficient to send it to the Moon along with the payload. The combined weight of spent rocket and payload was on the order of 1,500 kilograms.

When the Russians were ready to begin test flights leading toward placing man in orbit, they used this same upper stage on the original launch vehicle. It was not until 1967 that a replica of Vostok 1 was put on public display (Paris Air Show), and indeed, the upper stage of that assembly was essentially the same as the earlier unveiled lunar stage of 1959.

It was mentioned that at first Western analysts thought a much smaller rocket had been used by the Russians for the launch of Sputnik 1 because that payload weighed only 84 kilograms, and people at first were unaware of the great weight of accompanying rocket stage also in orbit. A second factor in the underestimation was the difference in design philosophy. For example, the early U.S. Atlas missile has such light construction that it must be kept pressurized all the time to keep it from collapsing of its own weight in relation to skin thickness.

This was done to maximize performance for a given size of vehicle. By contrast, when the Soviet launch vehicle arrived by ship at Rouen, France, observers were fascinated to note that the core and boosters were unloaded with cables attached at opposite ends, and workmen could walk the length of the empty rockets. The implication was the Russians did not feel weight-limited, and had built rugged vehicles which still permitted them to carry the payload they wanted, within reasonable limits.

3. Launch Vehicle with Improved Planetary Upper Stage, A–2

The Luna and Vostok version of the standard vehicle did not exploit the total potential of the first stages, and so an improved stage was built which began to fly as early as 1960. Its first public disclosure came in 1961 in connection with the Venus attempts of that year. The Luna upper stage was replaced by a stage 6.6 to 8 meters long. It was able to send about 1,500 kilograms of payload to the Moon, not counting the weight of an escape rocket, and over a period of time the capacity was raised. Without an escape rocket it was used to increase the Earth orbital capacity. The first announced use in Earth orbit was to put up 6,583 kilograms, and subsequently, the capacity has been described by them as 7,500 kilograms maximum. It was used for the pair of Voskhod manned flights, and has continued in use to the present time in the Soyuz manned flights. In addition it is the version most used in the Kosmos program for those flights which perform a military mission followed by recovery after some days.

It is the Soviet practice to disclose information only piecemeal about their vehicles. In the case of the Vostok it was years before they disclosed the thrust of the rockets or their number. The sole statistic beside the orbital weight was an output of 20,000,000 horsepower, not a common measure for describing the power of rockets. As mentioned they later said the combined thrust was 600 metric tons from six engines.

When the Voskhod flights came, they said the rocket had seven engines of 650 metric tons. No replica was put on display, so that analysis in the West was made more difficult. Subtraction of the announced thrust of the five core and booster engines seemed to leave 140 metric tons of thrust for an upper stage of 2 engines. This was not logical for the purposes or for the observed behavior of the flights. It is only in 1975 that we finally have a fresh Soviet statement on this rocket combination. First of all, they have adjusted downward the thrust of the central core rocket to list it at 96 metric tons, giving 504 metric tons for the combined thrust of the core and boosters. Now they list the same upper planetary stage, as used for Soyuz as having a thrust of 30 metric tons. The stage is powered by a single engine with four combustion chambers and nozzles. There is no clue as to how to reconcile the 534 metric tons of combined thrust in Soyuz with the 650 metric tons quoted for the same stages in the Voskhod of many years earlier. We still do not know what the seventh engine alluded to earlier meant, as only six can be counted.

The mystery of why the Soviet listed thrusts ran ahead of normal reality was finally solved in 1975. Maarten Houtman of Amsterdam was talking with a Soviet engineer at the Paris Air Show, and was told that the 600-metric ton figure for thrust was found by adding to-

gether the combined thrust of four RD–107 engines at 102 tons each, plus the RD–108 engine at 96 tons, for a total of 504 tons, and then adding to that the thrust of the same RD–108 which continued to burn after the four strap-ons dropped away, making the total of 600. The arithmetic is impeccable, but it seems a most peculiar way to count total thrust, and it still ignores the thrust of the final stage.

A review of the book by Leonid Vladimirov (Finkelstein) shows that he published in 1971 the thrusts of the Vostok (A–1) rocket four years ahead of the 1975 Soyuz disclosures on the same rocket, and he further had information that the mysterious upper stage had a thrust of 11 tons, which is consistent with the RD–119 engine to be discussed presently.[15]

4. The Added Stage Version for Eccentric Orbit and Escape Missions, A–2–e

The A–2 version, just described, was itself a step back from the A–2–e, already partly described. In this version, there was indeed a seventh engine, in contrast to Voskhod and Soyuz. This added stage when used is contained within the shroud which covers the payload. The Russians after Luna 3 used consistently a special technique for their flights which required an extra stage. This was especially important for flights more nearly in the plane of the equator, since the Soviet launch sites are at relatively northern latitudes. The rocket assembly is launched from the cosmodrome to place the interplanetary larger stage plus the payload in low circular Earth orbit, where the burned out stage is separated. During the course of the first orbit as the payload heads northeast across the South Atlantic to cross Africa, a special orbital launch platform, never specifically described as to shape, dimensions, or weight, is oriented and from it the final payload is launched to higher speed by the escape rocket. This probe rocket, after it has done its work, is separated from the payload and flies on essentially the path as the payload. It has not been described in detail in Soviet publications available in the West. However, it was shown diagrammatically in a Soviet pamphlet written in German, "Nachrichtenbrüke in Kosmos" which described Molniya 1. This has subsequently been issued in English: "A Satellite's Overhead". The stage is shown as a stubby cylinder measuring about 2 meters in diameter and perhaps 2.5 meters long. The Royal Aircraft Establishment estimates its length as 2 meters. Soviet payloads which are launched from the orbital launch platforms and given their impetus with this added escape stage also carry a special maneuvering engine for orbit adjustments and smaller verniers for orientation.

When this whole system works, it does a very effective job. The Soviet program is given added flexibility as to launch windows through the technique of orbital launch, and calculations can be made as to the final stage firing in the relative tranquility of the vacuum of space. This flexibility is important for the Russians who have lacked the worldwide network of land-based tracking and control stations which the United States has developed in cooperation with other nations. But the number of steps required to carry out a deep space mission, supported by automatic devices and a few ships, tended to expose these

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[15] Vladimirov, Leonid, The Russian Space Bluff. London: Tom Stacey Ltd., 1971, p. 83.

operations to a fairly high failure rate. Assuming that in general Soviet flight successes and failures are comparable to those of the United States because competent people in both countries are applying the same technology, then we see no particular reason why Soviet Earth orbital operations should be any less successful than those of the United States. But deep space work with the platform launch technique presents in fact another story. For example, the United States has made 59 launch attempts for escape missions, of which only 11, or 19 percent, have failed to escape. The Soviet Union has made an unpublished number of attempts to use the orbital launch technique, but we can note that of 65 Earth orbiting platforms carrying payloads intended for the Moon, Mars, or Venus, 20 failed to send their probe payloads beyond Earth orbit, or a failure rate of 31 percent, higher than the U.S. rate. The total failure rate is undoubtedly higher for deep space missions because additional flights presumably did not even attain Earth orbit.

5. The Standard Vehicle with Maneuvering Stage, A–m

Late in 1963 and again in 1964, the Russians flew payloads with the name Polet, and these were heralded as but the first ones of a large series. In actual fact, no more flights occurred with exactly the same characteristics, and the name itself was not used again.

What was distinctive about these flights was that they came early enough in the Soviet program and were ambitious enough in performance for their being an application of the A vehicle. They were launched from Tyuratam. Each was advertised to have made extensive changes of altitude and also of orbital plane. However, the amount of plane change was not specified, and it is doubtful that it was very large. Neither flight left a separated carrier rocket in orbit as a guide to how extreme the subsequent maneuvers were of the final payload. So apparently the A–1 or A–2 were not used for these launches, but some experimental maneuvering stage which remained attached to the payload. Either this combination did not work out as hoped, or the "m" stage subsequently has been incorporated into other hardware, to be discussed later.

6. The Standard Vehicle Possibly in an A–1–m Configuration

There were two more engineering test flights which bore at least a partial resemblance to the Polet flights. These occurred in 1965 and 1966 under the labels Kosmos 102 and 125. There were no separated carrier rockets accompanying the flights, and their location of perigee in the southern hemisphere suggested that their lunar type stages had been only suborbital with an integral upper stage firing half way through the first orbit to put the apogee back in the latitude of the launch site. It is a temptation to consider this a further development of the use of the "m" stage, but without Soviet data, it is not provable.

7. The Standard Vehicle Possibly in an A–2–m Configuration

In 1970 and 1971 there were three flights (Kosmos 379, 398, and 434) which have never been adequately explained. In another context, their possible missions will be examined. They behaved a little like regular A–2–e vehicles in that they abandoned an interplanetary type stage in low Earth orbit after their launch from Tyuratam. Later they abandoned some piece of hardware in an eccentric orbit which reached

out to approximately 1,200 kilometers. After this a maneuvering engine integral with the payload carried the flight to a distance of between 11,000 and 14,000 kilometers, depending on the flight. It is possible that this was therefore a series of flights using the A–2–m configuration. On the other hand, supposing that the hardware abandoned in an intermediate orbit was an "e" upper stage, then the payload may have incorporated a new fourth stage of high efficiency, and it might be labeled the A–2–e–h combination. Until there are more flights to give us data points, or a Soviet explanation, we may be left with no firm answer possible.

Elsewhere in this chapter, Table 1–10 attempts a synthesis of the data collected in Tables 1–8 and 1–9 to suggest a possible set of relationships among the rocket engines and stages used in different vehicle assemblies. It must be stressed that this is somewhat of an exercise in building a castle of sand. One good wave of new Soviet disclosures even if not crumbling the whole structure would change some of its parapets and towers of speculation.

B. THE SMALL UTILITY LAUNCH VEHICLE ("B")

Just as the United States looked to the Redstone, Thor, Jupiter, Atlas, and Titan in the missile inventory to serve as first stages of space launch vehicles, the Russians also saw the logic of applying the results of extensive military R & D. As discussed, the original ICBM, SS–6 or Sapwood became the standard Soviet launch vehicle from 1957 to the present time, with its lift capability gradually improved to as much as 7.5 metric tons. Even with the economies of serial production, this is still an expensive way to put up every payload whose weight may be a small fraction of 7.5 metric tons.

Moscow parades of military hardware had revealed medium range and intermediate range missiles which should have been quite capable of serving as the first stage of space launch vehicles. One of these, the SS–3 or Shyster was later pictured by the Russians as the largest of four classes of vertical probe rockets used for geophysical payloads and biological flights launched at Kapustin Yar during the late 1950's. Shyster was replaced in parades by an improved version which may have a range of about 1,600 kilometers instead of about 1,000 kilometers like its predecessor. This newer model was code named SS–4 or Sandal. It was the principal rocket which showed up in Cuba during the fall of 1962, so its picture became well known in the United States.

Kapustin Yar, a primary base for test flights of the Shyster and then the Sandal missile, came into use as a space orbital launch site in March of 1962 when Kosmos 1 was announced. The small Kosmos flights, all flown at close to 49 or 48 degree inclinations would have been ideally launched by the Sandal, and that was the conclusion of Western analysts for five years. No specific weights were announced for these groups of Kosmos payloads, strongly suggesting that there would be a large military component among them. However, from a study of the replica payloads which have been put on display, this vehicle should be able to lift from 260 to 425 kilograms to orbit. A Soviet official at the Montreal Expo told David Woods the range was 280 to 600 kilograms. In 1967 at the Paris Air Show, the Russians put on display for the first time the RD–119 upper stage rocket used for

this launch vehicle. It had been developed between 1958 and 1962 at the Leningrad Gas Dynamics Laboratory. Its design concept was a little like the RD–107 and RD–108 from the same source. It operates at a pressure of 80 atmospheres, has a thrust of 11 tons, and a vacuum I_{SP} of 353 seconds. It burns unsymmetrical dimethyl hydrazine (UDMH) and perhaps liquid oxygen. The single nozzle is bell-shaped, and a single shaft turbo pump system drives the fuel and oxidizer supplies as well as fairly elaborate set of auxiliary nozzles for roll, pitch, and yaw.

Late in 1967, with the expansion of the Moscow Museum of Industrial Achievement, a total assembly of this small Kosmos launcher was put on display. This confirmed the analysts had been right: It did use a modified SS–4 Sandal first stage, with an added upper stage powered by the RD–119. Most of the payloads it puts up are spin stabilized, and then the carrier rocket upper stage is separated. In at least one case, the payload was not separated. In another case, two payloads were put up in a single launch. Twice, a special aerodynamic stabilization was used. More recently the first stage rocket engine has been displayed as the RD–214. It has four nozzles, burns kerosene in refined form and nitric acid. Its thrust is 72 tons, the I_{sp} is 264 seconds, and its chamber pressure is 45 atmospheres.

Although this study is devoted to the space program and not to military hardware per se, so much reference is made to military surface-to-surface missiles, many of which are also used for space purposes that Table 1–10 has been appended to give a quick reference check list of the better known of these.

C. THE FLEXIBLE INTERMEDIATE LAUNCH VEHICLE ("C")

Small, relatively modest Soviet payloads for five years came only from Kapustin Yar, and after that also from Plesetsk, but not from Tyuratam. In 1964, however, a new series of flights began at Tyuratam with a vehicle which was neither a B–1, nor the large A class. It can be designated the C–1, and starting in 1967 it also came into use at Plesetsk. It was first used for a space launch from Kapustin Yar in 1973.

As first used, it put up multiple payloads, initially three at a time, then five at a time, and now eight at a time. Starting at the end of 1965 and most of the flights since have been single payloads. The earliest launches were in eccentric orbits, and then came flights with circularized orbits, and these have been at increasing altitudes.

This performance seemed in excess of what could be expected of the B–1 launch vehicle both because of the many multiple payloads, and the demonstrated capacity to achieve circularized orbit at higher altitudes. In addition to that the appearance of the flights from a cosmodrome not used for the regular small Kosmos or B–1 flights was a further indication. Even where flights of the B–1 and the C–1 come from the same cosmodrome, there are marked differences in inclination, suggesting the use of different launch pads.

As Western analysts sought a military missile which might fit the needs of a first stage of the C–1, the SS–5 or Skean came to mind. This had been paraded in Moscow, and was believed to have a range as a missile of close to 4,000 kilometers. It was also known as the missile which followed the Sandal into Cuba and posed an added threat then because of its greater range.

The Skean-based C–1 type of launch vehicle has not yet been put on display by the Russians, but finally some photographs are appearing, and they confirm the use of this particular missile for the first stage. The first photograph was obtained in the West by Maarten Houtman of the Netherlands. The exact dimensions are not known, but some ratios have been developed by Phillip S. Clark of the United Kingdom. The vehicle may be as much as 2.5 meters in diameter although it may be 2.4 or 2.25 meters and about 31.6 meters long. It probably could put over 1,000 kilograms into low Earth orbit but has not been used that way. More likely the payloads range from about 900 to 500 kilograms, decreasing with altitude. The reticence to disclose anything about its rocket engines or performance again suggest a role which is largely military. Even the Skean missile when paraded in Moscow carried a plate to hide its power plant. Kenneth Gatland says it has four nozzles.

D. THE NON-MILITARY LARGE LAUNCH VEHICLE ("D")

In the United States the time came when occasional needs for putting up large space payloads exceeded the capacity of existing varieties of military missiles, and hence the Saturn I and I B were created. They grew out of preliminary designs of the Army Ballistic Missile Agency Redstone Arsenal team headed by Wernher von Braun. Much the same need must have been felt in the Soviet Union, and they, too, have created their first non-military-missile vehicle for space purposes. Some Western analysts speculate it was first designed as a super ICBM to carry the 100 megaton city buster warheads that Premier Khrushchev talked about. In any case, its flight test program has been limited to space work.

1. The Basic Vehicle without Extra Stages, D

The first launch of a new large vehicle came in July 1965, with a payload named Proton 1, and said to weigh 12.2 metric tons. The payload replica was put on display and it had a cylindrical cross section of about 4 meters. When the payload was orbited, it was accompanied by a separated spent carrier rocket stage. Published Western estimates of this stage have ranged between 12 and 27.7 meters in length, and these different figures in turn have raised issues not fully resolved about the first three Proton flights.

The vehicle has not yet been put on public display, even though it has been flying for ten years, noı has a complete photograph been shown. Motion pictures of launches, released in the last year or so tantalizingly show the upper stage and payload, and also the attachment points of strapped on boosters. Inflight pictures are too fuzzy to do more than reveal that there are six boosters firing at the time of ascension from the launch pad at Tyuratam.

The first careful drawing of the vehicle based upon these partial looks was done by Peter Smolders of The Netherlands.[16] He postulated that the general appearance was that of a scaled up A class vehicle with six instead of four boosters. Subsequently closer study by Charles P. Vick and others in the United States builds a case for the same essential operation of boosters, but that these may be regular cylinders

[16] Smolders, P. L. L., Soviets in Space, London : Lutterworth Press, 1973, pp. 70–71.

through most of their length rather than the tapered design used for the A class vehicles. There may be a brief transition at the upper end into a conical fairing to the point of attachment to the sustainer core rocket.[17]

When the first launch occurred the Russians heralded this vehicle as opening the door to many important space uses. These included the construction of manned space stations and unmanned flight to the planets. It was given a brief and non-explicit description, generally said to produce about three times the horsepower of the A vehicle.

If one makes the assumption that the same design philosophy was used, and this seems borne out by the limited looks provided in Soviet films, then the vehicle should be much like an A vehicle scaled up in volume three-fold (or 1.44 times linear), with the likely change that the boosters are mostly cylindrical. Holding to the same proportions, the basic vehicle sustainer core should be about 40.7 meters long. The combined thrust of the core plus six boosters should be on the order of about 1,542,000 kilograms, or close to 220 metric tons of thrust for each engine. Any simple three-fold scaling presents contradictions. If one assumes the A vehicle would lift 3,000 kilograms, the D vehicle should lift about 9,000 kilograms. If the A–1 and A–2 lift in the range of 4,725 to 7,500 kilograms, then the D–1 should lift about 14,175 to 22,500 kilograms. The first three Proton payloads were 12,200 kilograms, not an ideal fit for the D or D–1. The fourth Proton at 17,000 kilograms was in the right range. If the estimated length of the accompanying orbital rocket for the early Protons was 27.7 meters, that is too short to be the sustainer core which may be 40.7 meters long, if operating in the "A" class burn sequence. The problems with both weight lifting capacity and length tend to minimize the chance that the first Protons were put up in the same fashion as Sputnik 1 through 3. We have to allow for the possibility of a D version but the case is not strong. Vick prefers the notion that the core vehicle is ignited at altitude rather than at ground level. But he suggests that if this long stage went into orbit, it might weigh enough to explain the relatively low payload weight of the first three Protons.

2. The Improved Vehicle with an Added Stage, D–1

If the D vehicle was to demonstrate its potential in more ambitious flights, it needed one or more added stages, and, as discussed, may have had an additional stage from the outset. Applying the proportions of the A–2 interplanetary stage and scaling up three fold, its 8 meters should be about 11.6 meters on the larger vehicle. This is compatible with the 12 meter length assumed by the Royal Aircraft Establishment in its publications.

One notes that the Saturn I with a first stage thrust of about 680 metric tons would put up 9,072 kilograms of payload, and the Saturn I B would put up closer to 18,500 kilograms. Considering the first stage thrust of the D class vehicles as perhaps 1,542 metric tons, then at the same level of efficiency and same use, the D class vehicles should have the potential to put up payload weights in the range of 20,570 to 41,950 kilograms. In fact, one must scale this back both because there is no evidence for the Soviet use of LOX-hydrogen fuel in upper stages,

[17] Vick, Charles P., The Soviet Superboosters—1, Spaceflight, London, December, 1973, pp. 457–471.

and because the launch site is less favorably located than Cape Canaveral. In addition to that is the Soviet design philosophy which tries to offset heavier structures for launch vehicles with more thrust, this combination being at the expense of payload weight.

In the first half of 1967 came two Kosmos launches, 146 and 154. These were given routine anouncement by the Russians, but British optical measurements showed a carrier rocket in orbit larger than the interplanetary stage of the A–2 rocket, and smaller that the possible 27.7 meter length associated by some estimates with the first Proton launches. The payloads were estimated at 14.2 meters in length by 3 meters in diameter. One must recognize that a small number of readings of an indirect nature which make some assumptions about shape and surface must render all measurements that are very tentative. The British estimate at the time was that the payloads in question might lie in the 18,000 to 27,000 kilogram range. These numbers would square generally with use of the D–1 launch vehicle.[18]

What we do not know is whether these flights performed their missions as intended in low Earth orbit, or were intended to fire probe rockets (making them D–1–e) into some further trajectory.

In November 1968, Proton 4 was launched into orbit, and seemed to be accompanied by a 12-meter spent rocket casing. The Russians announced a weight for the payload of 17 metric tons, reasonably close to the Western estimate of 18 metric tons for the D–1.

The first Salyut space stations also put up by the D–1 seem to have had a weight of about 18.6 metric tons. With reports that they are likely in the future to grow to a weight of closer to 25 metric tons, this might still be within the capacity of the D–1, but pushing close to the possible upper limit.

3. The Improved Vehicle with Regular Upper Stage plus an Escape Stage. D–1–e

During 1968, several Zond flights were made into deep space and around the Moon, some to return to Earth for successful recovery. These were identified as capable of carrying men. Of the known vehicles, only the D–1 with added stage should have the capacity to carry a crew on a circumlunar voyage. The pictures which ultimately were released of the Zond 4 through 8 series showed a craft which looked like a Soyuz without its work compartment but with a high gain antenna for long range communications. Because the Soyuz weighs about 6,570 kilograms, the Zond may be in the same range, but more probably lower such as 5,800 or even 5,300 kilograms saving weight on the work compartment but carrying added maneuvering fuel.

The D–1–e vehicle came into further use in 1969 for the unmanned Luna flights starting with Luna 15. Only occasionally have weights been announced. Luna 16 was listed as having landed 1,880 kilograms on the Moon, which is generally compatible with what one would expect. Since the Russians have announced an A–2–e payload of 1,640 kilograms sent to the vicinity of the Moon (Luna 11) and 1,180 kilograms sent to the vicinity of Venus, then a three fold increase with use of the D–1–e would give 4,920 kilograms and 3,540 kilograms respectively. In fact the D–1–e likely does better. For lunar flights, it probably can carry payload in the range of 4,820 to 6,500 (more likely

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[18] Flight International, London, March 30, 1967, p. 495.

between 5,300 and 5,800); and for planetary flights to Venus or Mars, depending on the year it can probably deliver between 3,500 and 5,000 kilograms. These numbers square with the only announced weights for Mars 2 and 3 at 4,650 kilograms. The D–1–e has now also been used to place several payloads in 24-hour circular orbit close to a fixed position over the Equator.

4. The Possible Use of a D–1–m Version

In December 1970, Kosmos 382 was launched with only a routine announcement of its initial orbit, which ranged from 320 kilometers to 5,040 kilometers at an inclination of 51.6 degrees. Western observers noted that it had the same kind of man-related telemetry and frequencies as used for the Soyuz program and the other Kosmos flights starting with 379 which might have been launched by an A–2–m vehicle. But Kosmos 382 was different in its performance. It was maneuvered upward to 1,615 kilometers by 5,072 kilometers, and then again from 2,577 kilometers to 5,082 kilometers. In addition, on the last maneuver, the orbital plane was shifted to move the inclination from 51.6 degrees to 55.9 degrees. This was something that involved energy expenditures for a payload, presumably large enough to carry a human crew, that was beyond the capacity of any A–2 class vehicle. Consequently, it has been judged to be a version of the D–1. Since it used a platform launch technique, it left a spent carrier rocket and platform in the initial orbit reported by the Russians. Its subsequent multiple burns went beyond the performance of previous escape rockets. Hence one is led to the possibility of a D–1–m combination, with an improved maneuvering stage. Some people would suggest calling it a D–1–h, indicating that the upper stage not only maneuvered but demonstrated some special high performance.

If at some point the Russians bring in a new family of upper stages propelled by high energy fuels as the United States has done, we should see further increases in the lifting capacity of these A–2–e and A–2–m as well as D–1–e and D–1–m vehicles.

E. THE MILITARY COMBAT SPACE VEHICLE ("F")

The cumbersome SS–6 Sapwood ICBM represented a beginning for the Soviet intercontinental missile stockpile, but its use of cryogenics, and awkward shape for potential silo use must have indicated fairly early that despite its continuing usefulness for space, it was not especially good for missile purposes, unless these were first strike.

In a 1967 article in *Red Star*, General Tolubko stated that these surface launches of the [Sapwood] took a long time to prepare and that later version rockets were smaller and placed in silos.[19]

As Soviet missile capabilities improved, they conducted more and more tests at the principal test site of Tyuratam which extended to the Kamchatka target areas, and then beyond to the mid-Pacific. These flights were often protested by the Japanese when target area closures were announced by the Russians. Photographs released by the United States Government of Soviet missile tracking ships in mid-Pacific and even of splashes of reentry bodies suggested that the United States

[19] Tolubko, V. F. Strategic Intercontinental . . . Krasnaya Zvezda, Moscow. November 18, 1967, p. 1A.

was monitoring Soviet tests in the same way that Soviet ships monitor U.S. missile tests. The Russians have always described these Pacific tests as further tests of carrier rockets, often signalling through variation in the language that new models were coming into the test program, rather than just continuation of earlier series. The observations made of the flights suggest they have definitely been tests of military missiles, not space carrier rockets as such. Every so often in the past, Soviet military leaders made specific reference to the high accuracy with which these tests delivered the "penultimate" stage of the carrier rockets to the assigned area.

As Table 1–11 summarizes, the Western powers have assigned SS designators up through the SS–20 so far, and there are NATO code names for most but not all of these, depending on whether they have been available on display or pictured in clear photographs. Of the longer range missiles, the SS–4, SS–5, and SS–6 have already been discussed in the context of their adaptation to space flight. At one time the SS–7 Saddler made up a large part of the Soviet missile inventory, but it was never put into a Moscow parade, and so far as can be judged was not adapted for space use. It was apparently a fairly modest capacity ICBM, which may have been the missile once shown in a rather blurred film clip from a Soviet movie and pictured on the cover of *Missiles and Rockets* magazine in the United States. The SS–8 Sasin was paraded in Moscow for a number of years, as the first Soviet ICBM ever given such public exposure. It seems never to have played a very prominent part in the inventory, but did become operational. According to U.S. Department of Defense testimony before Congress, the SS–11 replaced the SS–7 as the principal part of the Soviet ICBM inventory. Despite its extensive use, it has not been paraded in Moscow, and it does not seem to have come into space use. Having been hidden so carefully, it lacked any publicly known NATO code name until quite recently, but is now called Sego. It was also of relatively modest capacity.

Three other ICBM class missiles have been paraded in Moscow. These are the SS–9, SS–10, and SS–13. Taking them in reverse order, the SS–13 Savage is the technological equivalent of a Minuteman. But the Russians seem not to have favored solid propellant missiles for long range missile or space launch use. Some observers have said this is because their chemistry has not kept up with the same state of the art attained in the United States. In general, the Russians have moved from the early cryogenic systems to storable liquid propellants. The SS–10 Scrag was first paraded in May 1965 and has not been seen since 1971. It was a long, cigar shaped three-stage rocket described by the Russians as "akin" to the Vostok launcher (which was then still two years away from its first public unveiling). The stages were joined by open truss sections. The Russians also hinted that this vehicle was capable of putting a bomb in orbit for delivery to any place on Earth. In November 1965, when it was paraded again, the Russians were a little defensive in their comments stressing it did not violate any treaty restrictions on use of space weapons because such agreements prohibited their use, not their production. Further, they said in a sense, every ICBM is a space weapon, anyway, as all such missiles fly through space, and their use is permitted under the terms of the space treaty.

1. Use as a Weapons Carrier, F–1–r

When Soviet test flights of fractional orbit bombardment systems (FOBS, see Chapter Six) began in 1966, unofficial Western observers wondered if they were seeing the SS–10 Scrag being flown. Later, the U.S. Department of Defense credited the FOBS flights to the SS–9 Scarp with added stages. Apparently the SS–10 Scrag never entered the operational inventory. It was paraded again in May 1966 and November 1966. The same brief description of its orbital use continued. However, when it was paraded in November 1967, no reference was made to an orbital capacity, and in the parade appeared for the first time the SS–9 Scarp. The TASS report on this new SS–9 was:

> The last to appear were mammoth rockets each of which can deliver to target nuclear warheads of tremendous power . . . . These rockets can be used for intercontinental and orbital launchings.[20]

The SS–9 has indeed become an important element in the Soviet arsenal, and in retrospect it is possible to trace its further extension to use in the space program as well, for missions closely allied with military functions, but not the more civilian and scientific part of the space program.

In December 1965, the Russians announced rocket tests which they called tests of "landing systems" with "some elements" falling in the Pacific (staging, not payloads), which fitted the operational pattern of FOBS flights which came later. In November 1966, General Dankevich associated orbital rockets with silo launches, and said these vehicles carried very large warheads.[21] Secretary Laird in the United States stated that the SS–9 Scarp was the carrier of the FOBS system.[22]

The SS–9 Scarp was paraded as a 33.2–35 meter long, bottle-shaped rocket, with a principal diameter of 3 meters. In the parade the warhead section was about 1.15 meters in diameter, then expanding into a cone to join the main 3 meter diameter cylinder. It is hard to tell precisely whether the SS–9 Scarp as paraded was a two or three stage vehicle. It may have been divided at about 17.5–19.7 meters up from the base, with perhaps another 10.4–8.5 meters making up the second stage, and 5.3 meters making up either a third stage with warhead or simply a warhead.

Since for two years the SS–10 Scrag was described as an orbital weapon, it is possible that the third stage of that vehicle was transferred to the SS–9 Scarp for a further version which has not been pictured or put on display. In some of its space uses, a fourth stage is also required, to account for the patterns of debris or expended rocket casings which can be observed in flight.

Our interest in this rocket in the context of this report is as a military space payload carrier, the F–1–r or F–1–m. We cannot say what the whole assemblage looks like today. From parade views, we know the first stage is quite different from the A class vehicles. While the A class uses a core with four strap-on boosters, for a total of 20 nozzles, the F class first stage shows 6 nozzles visible, while a plate covers the center part of the base, which could hide a seventh central nozzle.

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[20] TASS, Moscow, 0710 GMT, November 7, 1967.
[21] Dankevich, P. E., Interview on Moscow Radio, 1430 GMT, November 18, 1966.
[22] Laird, Melvin R. Fiscal year 1971 Defense Program and Budget, February 20, 1970, p. 103.

The first known space use of the system was for FOBS tests, apparently in a four stage version. The first stage is suborbital. A carrier rocket stage, whether second stage or third stage is not clear, is abandoned in the initial orbit attained. The Royal Aircraft Establishment gives its dimensions as 8 meters long by 2.5 meters in diameter. In flight, a further change in orbit occurs, and this places an orbital platform in still another position. It is from this latter object that retrofire occurs (hence the designator "r" symbolizing the retrofire fourth stage) which drives the warhead back to Earth, while the rest of the orbiting hardware continues in space for at least a few more orbits.

2. Use as a Maneuvering Vehicle, F–1–m.

The F class vehicles have now appeared in several other flight modes. and these will be discussed in a later chapter. The essential change in the hardware is the appearance of a fourth maneuvering stage which may be the outgrowth of work started in the Polet and Kosmos 102 and 125 programs. These can be labeled the F–1–m series, although there may be subtypes to fit the different flight modes which have been observed. All the F class space payloads have been launched from Tyuratam. The weapons-related flights have been at an inclination of 49.5 degrees. The maneuvering flights, for a variety of military purposes in the general range of from 62 to 66 degrees inclination. These additional missions seem to relate to inspector/destructor flights, radar ocean surveillance, and possibly other uses.

F. THE VERY HEAVY LAUNCH VEHICLE, ("G")

Perhaps the most elusive space launch vehicle in the Soviet collection is their very heavy system. The need for such a system is highly compelling if the Russians have been serious in their interest in both manned lunar flight and later manned planetary flight. They have talked a great deal about orbital assembly of orbital stations and deep space manned craft, but the actual use of orbital assembly has not kept pace with the talk and rumors of what they may be planning to do. Some of these possibilities will be discussed later in this study.

While orbital assembly is seen by Soviet space officials as the ultimate technique for many advanced missions, the availability of a large launch vehicle would serve Soviet interests at an earlier date in the same way the Saturn V was of use to the United States. Even when assembly is commonplace, putting up some heavy and complex components with a large launch vehicle has advantages.

Over the years, the Russians have taken some special pride in building large aircraft, hydroelectric dams, drag lines, battle tanks, artillery. They have in the past stressed their leadership in high payload weights in space. One can imagine that a very large space launch vehicle would find a place in their hardware development. However, because they have treated all space propulsion details as sensitive information, they usually have waited some years after launch vehicles became operational before revealing details about them. This has been evident in the text of this chapter. Consequently, it is very difficult to find specific Soviet statements about a very large vehicle.

In the United States, however, there have been statements by the most senior NASA officials through 1970 that such a Soviet very

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heavy lift vehicle has been under development. Indeed, it has even been described as having the general capacity of the Saturn V. Depending upon what assumptions one makes about upper stage efficiency, its lift capacity for several missions can be variously estimated. If it was originally intended to fly during the late 1960's, it can be speculated that perhaps some or all of the stages of the D–1–e vehicle related to Proton, Zond, deep space, and Salyut payloads, would represent a shortcut way to attain an earlier operational capability. This would be akin to the U.S. use of the S–IVB stage on Saturn V or the Centaur stage on Titan III. Since the D–1–e vehicle does not demonstrate the kind of lifting efficiency associated with high energy fuels, then perhaps the G–1–e heavy lift vehicle also will fall short of its full potential in early use. The NASA estimates about the Soviet vehicle put the first stage thrust in the range of 4.5 to 6.35 thousand metric tons, compared with 3.4 thousand metric tons of the Saturn V. But without high energy fuels, that might mean a capacity to deliver about the same 45,500 kilograms to the vicinity of the Moon which a Saturn V typically will send.

How reliable can such estimates be? That is hard to say for a vehicle which the Russians have not discussed in specific terms, and which in any case is too big to be paraded. But since the "national technical means" which are used to count Soviet missile silos and slight differences in their dimensions are freely cited by Secretaries of Defense, one has to assume that this Nation should have a fair idea of the scope of work associated with such a postulated large vehicle.

The Russians themselves have thoroughly obscured the issue of whether in fact such a vehicle exists. Some have praised the economy of orbital assembly over direct flights to the Moon with a big vehicle. On November 12, 1965, Cosmonaut Nikolayev stated in a Sovio radio interview that studies were underway to see whether manned flights into deep space should be solely through orbital assembly or also through use of a large vehicle for direct flights. By July 1966, a Czech commentator, Jan Petranek, was talking in terms of a 100,000-kilogram-payload ship.[23] In March, 1967, General Kamanin, the leader of the cosmonaut corps was predicting flights to the Moon of payloads in the 60,000 to 70,000 kilogram range.[24] This might have meant through orbital assembly, but if based upon use of high energy fuel in upper stages would scale well with the 4.5 to 6.35 thousand metric ton thrust first stage for the G class vehicles, since a Saturn V at 3.4 thousand metric tons thrust would deliver 45,500 kilograms on a similar mission.

One of the most specific forecasts of a very large Soviet vehicle was written by Karel Pacner of Czechoslovakia in the October 4, 1967 issue of the Prague magazine *Student*, in which he specifically credited Cosmonaut Popovich and General Kamanin as saying the very large vehicle was under preparation, that is, a vehicle well ahead of the D class. By October 1967, Cosmonaut Feoktistov, who was a senior official of the space design bureau, was quoted in *Pravda* as forecasting deep space flights using both the approach of Earth orbital assembly and direct from the surface of the Earth with [large] vehicles.[25] In March

[23] Petranek, Jan, quoted on Prague Radio, 1530 GMT, July 21, 1966.
[24] Kamanin, N., quoted on Warsaw Radio, 1900 GMT, March 9, 1967.
[25] Quoted by Moscow Radio, 0300 GMT, October 3, 1967.

1968 at Frankfurt, Leonid Sedov, the important space academician, stated there were now larger rockets in existence which were used exclusively for space, as opposed to adapted military rockets, and that these could support flights to the Moon and planets. The rocket required for landing on the Moon already existed, he said.[26]

Rumors and cosmonaut predictions of a manned lunar landing by the end of 1969 were prevalent in the first half of that year, and could reasonably have been supported only by flights of a large vehicle. It is hard to conclude the Russians were really ready for such a mission on the basis of public evidence, although some surprising development might have made it feasible. Alternatively, the Soviet predictions of that spring may have garbled plans for manned orbital flight around the Moon and also the automated return to Earth of lunar samples gathered by remotely controlled devices, rather than referring realistically to manned lunar landings that early. In any case, no successful flights of the big vehicle were accomplished, and the American press by early fall was repeating stories of uncertain origin that there had been a failure (or failures) of the big vehicle. It is obvious that hopes for any manned operations, whatever the missions, in 1969 were not met, including any time-competitive flight to rival Apollo 11, or any follow-on American flight if Apollo 11 had failed.

The next Soviet reference to a potentially large vehicle was by Academician Boris Petrov in August 1969 that a new type of vehicle would be used to place a large unmanned space station in orbit, that it was not necessary to send men to the Moon when automatic devices could perform the mission of bringing home rocks. He said that up to four Soyuz craft could then dock with this large new space station. While talking of ultimate flight to the Moon, he claimed that Luna 15 could not carry a man, but that the Zond class could; and further that some flights would be direct to the Moon.[27]

From these many speculative statements and inferences of the logic of how to achieve missions the Russians have repeatedly claimed were encompassed within their interest, it seems possible to postulate at least two versions of the large vehicle: One would be the G–1–e, intended for flight to the Moon; the other would be the G–1, intended for launching a space station core into Earth orbit. Later versions might substitute high energy fuel upper stages enhancing the performance over the levels estimated to be similar to the Saturn V.

One can speculate that any direct flight to the Moon with men would be beyond the capability of the G–1–e as described, since the Saturn V could not do this. Either a rendezvous operation would be required, or the G–1–e would have to be uprated with high energy fuels, to make it the equivalent of the one-time NASA design concept called Nova. Some of these possibilities will be explored in further details in a later chapter.

Meanwhile, what has happened to the class G vehicle? Some Western observers doubted that it ever existed. This seems unlikely, considering the need and the NASA official testimony. Charles P. Vick has even drafted a book about this vehicle which the public has not seen, with his findings summarized in *Spaceflight* magazine of London.[28]

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[26] Frankfurt Radio, 2020 GMT, March 20, 1968.
[27] Tokyo Kyodo, 0505 GMT, August 20, 1969.
[28] Vick, Charles P. The Soviet Super Boosters—2, Spaceflight, London. March 1974, p. 94.

Aviation Week has carried a number of times the apparent dates or periods that launch attempts were made with the G class vehicle, all of which failed.[29] If it is true that there have been three failures since the first attempt in 1969, this must have been very disappointing to the program managers. Now, six years later, we still have not seen a successful flight. The program may be as much as sixteen years old, and presumably a very heavy investment has been made in assembly, testing, and launch facilities as well as the cost of developing the flight articles. The investment is perhaps almost too much to write off, and future parts of the program depend upon successful development.

Charles P. Vick has made extensive studies of the Landsat pictures of the Tyuratam launch area, using pictures taken in several different wavelengths, and he is convinced he can pick out two very large launch pads and a major assembly building which support the G class vehicles. While his studies have tested a variety of hypotheses for various structures which might represent the design of the G class vehicles, it seems the data in the public domain are too scarce to come up with any real notion. Assuming that the vehicle uses some form of clustering as is true of both U.S. and Soviet vehicles of large size, and further assuming the configuration is anything like the A class vehicles, then the basic stages without escape stage and payload may measure on the order of 80 meters tall and with a base measure of 17 meters, or if there are fins, 21 meters. No one should be misled into thinking that these dimensions are the actual ones; rather, they merely show in terms of tankage how big a vehicle of the A configuration would be if the thrust were around 5.4 thousand metric tons.

This concludes the discussion of launch vehicles which either have been used successfully or there are strong grounds for suspecting have been tested for space purposes. Predictions for the future will be considered in another chapter. Some Western analysts have postulated a number of additional Soviet space launch vehicles, including one midway between the D and G vehicle sizes,[30] but this chapter has not speculated on vehicles which have not appeared in some form, as even dealing with the "known" vehicles has proven difficult enough.

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[29] Aviation Week, New York, March 17, 1975, p. 71 summarized these failures. See also Charles P. Vick, The Soviet Superboosters—2, Spaceflight, London, March 1974, pp. 94–104.

[30] For example, see: Stine, G. Harry, Some Strange Things Happened at Baykonur, in Analog Science Fiction/Science Fact, ---------- 1970, pp. 104–120.

TABLE 1-11.—SOVIET SURFACE-TO-SURFACE LAND-BASED STRATEGIC MISSILES

U.S. number	NATO name	Soviet designator	Stages	Propulsion	Launch mode	Guidance mode	Length	Diameter	Range	I.O.C.
SS-1A	Scunner	A-1	1	Liquid	Surface		?	?	?	?
SS-1B	Scud A	A-4	1	do	do		?	?	80	57
SS-1C	Scud B		1	do	do		?	?	300	65
SS-2	Sibling	A-2	1	do	do		?	?	?	?
SS-3	Shyster	A-3	1	do	do	Radio-inertial	21	1.6	?	?
SS-4	Sandal		1	do	Silo	do	21-22.4	1.6-1.65	1,900+	59
SS-5	Skean		1	do	do	Inertial	23-24.4	1.6-1.65	3,700+	61
SS-6	Sapwood		1½	do	Surface	Radio	31	10.3	8,000+	58
SS-7	Saddler		2	do	Silo	Inertial	31	3.0	10,000+	61
SS-8	Sasin		2	do	do	do	24.5-26	2.75	?	?
SS-9	Scarp		3	do	do	do	32.5-36.6	3.0	12,000+	65
SS-10	Scrag		3	do	do	do	35-37.8	3.0	8,000	
SS-11	Sego		2	do	do	do	19.5	1.85-2.5	10,000+	66
SS-12	Scaleboard		1	do	Mobile	do	11		800	69
SS-13	Savage		3	Solid	Silo	do	20	1.7	8,000+	68
SS-14	Scapegoat in Scamp		2	do	Mobile	do	10.6	1.4	4,000	?
SS-15	Sego(?) in Scrooge		2	Liquid	do	do	20	2	10,000+	?
SS-16			3	Solid	Silo	do	20	1.7	8,000+	75
SS-17			2	Liquid	do	do	24	2.5	10,000+	75
SS-18			2 or 3	do	do	do	37	3.0	12,000+	75
SS-19			2	do			20	2.5	10,000+	75
SS-20										

NOTES

1. This table should be used with care because the several sources differ sufficiently in dimensions, ranges, and other characteristics that none can be taken as literal truth.

2. The table at least provides a basic checklist of surface-to-surface land-based strategic missiles in the Soviet arsenal, both past and present. It should be remembered the Soviet Union has never published a list of its missiles, let alone given out their characteristics. Some of the ones in the list have been paraded in Moscow; a few also used as sounding rockets are in a Moscow museum.

3. The SS numbers and NATO code names have been disclosed over a period of years either in the trade press or in testimony before Congress by Department of Defense officials. Soviet designators for four sounding rockets have been revealed as listed.

4. The kind of propulsion and the mode of launch have generally been apparent either from parades or Soviet newsreel pictures. Early liquid-fueled rockets used cryogenics. More recent ones use storables.

5. The guidance mode is not always known. Some of the earlier rockets were radio-guided, and later shifted to inertial guidance in a few cases.

6. Lengths and diameters are probably accurate to within plus or minus 10 percent, but not much more.

7. The range numbers also differ widely from one source to another. Some were derived from congressional testimony or from assessments of the dimensions and structure of the rockets, or the landing zones in the Pacific Ocean when tests have been conducted. These, too, have changed over time as some missiles have been upgraded.

8. The IOC—initial operational capability year indicated also differs among sources, and hence is only approximate.

SOURCES: Tables appear in Jane's All the World's Missile Systems annual volume and in annual review tables carried in Flight International, in Aviation Week, in Air Force magazine, and in Interavia. Some other dimensions have been estimated by applying a scale to the silhouettes of models shown in printed congressional testimony of the posture reports each year by the Secretary of Defense and Chairman of the Joint Chiefs of Staff. Some data appeared in the now defunct British magazine, The Aeroplane.

IV. Tracking and Other Ground Support

A. COMMUNICATIONS NEEDS

Space operations require extensive support from Earth, including not only a launch pad with its associated assembly and checkout equipment, but also down range guidance and command, tracking, and other communications links. After the payload is in orbit, then tracking is useful for keeping posted on it and on all other objects in space, and for commands to the payload and receipt of data gathered or observed by the payload.

The Soviet Union may have started its space program with a curious mixture of very ambitious and comprehensive plans for use of large vehicles which could perform many missions in Earth orbit and beyond, combined with minimal support on the ground in terms of varieties of hardware, limited number of pads, and minimal communications links.

It is very likely that the early launch guidance was primarily by radio, radar and optical means because of the pattern of flying down the same corridor repetitively from Tyuratam; indeed this may still be true for many space launches, simply with more radio and theodolite tracking stations being added along additional corridors. This is suggested by the fact that vehicles which almost certainly must come from different launch pads, added when new types of vehicles were added, fly on inclinations that vary from the earlier standard ones only by an amount compatible with passing near some down range tracking points in about the same relationship as vehicles launched from the original pads.

Minimal ground support will permit the start of a program, but as needs to exploit the potential of space for science and applications grow, then more is required in Earth-based facilities.

B. EARTH ORBITAL TRACKING IN THE U.S.S.R.

Soviet public statements about their tracking capabilities for the early years made particular reference to optical tracking facilities. These were in many parts of their own country. They also encouraged observers in Soviet bloc countries to send reports of observations to Moscow. Some of the equipment was relatively simple: only a few more advanced telescope systems were pictured, with no indication of how many of these better systems there were.

Even with Soviet reticence in discussing more than optical tracking, there were Western reports of a network consisting of a master station and twelve others equipped with receivers to measure Doppler shifts in radio signals, tracking radars, and phototheodolites, transmiting data to a central computation center.[31] Four such stations were revealed as to location by the Russians in 1964 in a COSPAR report.[32]

The first official and more extensive listing came in connection with the Apollo Soyuz Test Project in 1975. This included the following seven land bases: Yevpatoriya, Tbilisi, Dzhusaly, Kolpashevo, Ulan-Ude, Ussuriyisk, and Petropavlovsk.[33] More likely than not, there are other stations to meet the needs of particular programs.

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[31] Aviation Week, New York, January 26, 1969, p. 26.
[32] Cospar Bulletin No. 18, Paris, April 1964, pp. 10–11.
[33] Aviation Week, New York, May 5, 1975, pp. 42–43.

In addition to tracking stations tied to specific programs, the Russians have a space defense system, akin to the facilities which feed data to Norad on this continent. There have been frequent references in the Western press to their ABM defense system, which of necessity is not only a missile launching system, but is also an elaborate tracking system, built around large arrays of radar referred to as Hen House. Any system which tracks long range strategic missiles also tracks space objects crossing Soviet territory or its approaches, regardless of nationality and absence of active signal emissions.

Because of the size of the Soviet Union in geographic terms, stretching as it does to a width close to two and a half times that of the continental contiguous United States, the domestic space tracking network does a better job of coverage than would a U.S. domestic system. But any worldwide tracking capability must extend beyond the political borders of any single nation.

C. FOREIGN TRACKING STATIONS

From the time of Vanguard on, the United States developed bilateral agreements with other nations to permit the establishment of tracking stations in all parts of the world, especially north and south through the Americas, essential to coverage of the satellites using minitrack. Then a similar system was developed for Project Mercury in an equatorial belt around the Earth. This has since supported Gemini and the Earth orbital operations of Apollo.

The Soviet Union either did not feel the same need for such complete coverage of its flights, being content to pick up recorded data as the flights went over their own territory, or perhaps they were reluctant to negotiate pacts with other countries which would expose the details of their data collection in the same open manner as the NASA program of the United States.

Hence, in a much more limited way they developed only a few largely unpublicized tracking stations in other countries, mostly places with a political climate favorable to the U.S.S.R. In December 1967, TASS referred to Soviet stations in the United Arab Republic (presumably Helwan), Mali, and "other" countries.[34] By April 1968, Guinea in West Africa was also named.[35] By October 1968, reference was made to a station in Cuba.[36] In February 1970, reference was made to a second station in the U.A.R., this one in Aswan.[37] In 1971, they added one in Fort Lamy, Chad.[38] From time to time there have been rumors and reports that the Russians put out feelers that they might like to establish tracking stations in such countries as Indonesia, Australia, and Chile. It is believed tracking is done at Khartoum in the Sudan, Afgoi in Somali, Kerguelen (South Indian Ocean) and Mirnyy (Antarctica).

D. SEA-BASED SUPPORT

Because of Soviet reluctance to become too dependent upon foreign land-based stations, or perhaps because not all nations approached were willing to be hosts, the Soviet Union has put considerable emphasis

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[34] TASS 0755 GMT, December 7, 1967.
[35] Moscow Radio, 1800 GMT, April 13, 1968.
[36] Granma, Havana, October 19, 1968, p. 6.
[37] TASS, 1940 GMT, February 8, 1970.
[38] TASS, 1719 GMT, February 8, 1972.

upon developing a sea-based support system. These consist of several classes of ships. One group operates in the mid-Pacific, and has been pictured in Western magazines and books. These are fairly impressive looking, loaded down with radomes and many specialized antennas and theodolites. They serve both to record missile tests, in the area where the dummy warhead is to splash; or in sight of the orbital path of spacecraft overflying the Pacific, usually for their initial revolution.

Other less well-equipped ships in comparison with the missile trackers have for some years operated in the tropical Atlantic and the Mediterranean along the path of orbital flights. Such ships would put into various ports in these parts of the world for supplies and crew rest, and when they left port it was usually an indication that new space launches were pending.

By noting what tracking ships are registered by the Russians as civilian type vessels, and which are treated as naval ships, it appears that the Pacific missile tracking ships whose pictures have been published after being photographed at sea by U.S. aircraft, are under the operational control of Soviet military authorities.

By contrast, the ships seen in the Atlantic and Mediterranean have now been identified as operating for the Soviet Academy of Sciences. Where once these ships were merchant vessels with only a minimum of modifications in appearance to serve the space program, now there has been a marked upgrading and even the development of highly sophisticated big ships with considerable communications equipment on board. In December 1967, the science ships were identified as the *Dolinsk*, *Bezhitsa*, *Ristna*, *Aksay*, *Morzhovets*, *Kegostrov*, *Nevel*, *Borovichi*, and *Kosmonavt Vladimir Komarov*.[39] Since that time virtually all of these ships have been named by the Russians as being in particular regions to support certain space flights, especially in the Atlantic, but also in the Indian Ocean. Subsequent to the 1967 listing, two progressively larger and better science tracking ships have been added: the *Akademik Sergey Korolev*, and the *Kosmonavt Yuriy Gagarin*. Details on the principal ships follow:

1. *Kosmonavt Vladimir Komarov*

This was the first of the greatly improved Soviet tracking ships. It appears to be a converted merchant ship hull of about 11,000 gross tons with an enlarged superstructure and several large radomes. It was first spotted by the West on a voyage through the English Channel while outbound from Leningrad to Havana, Cuba, which harbor it often frequented.

TASS in June 1970 said the ship has 1,000 or more berths, that it was built in 1967 at Leningrad, and has special computers and laboratories on board.[40] Pravda Ukrainy of June 23, 1970, said that it operated during the Soyuz 9 flight with a total complement of 240 men, including 125 scientists.[41]

The Russians have also said that communications between some spacecraft and Moscow can be maintained on a realtime basis even when not in direct view of the Soviet Union by having the *Kosmonavt*

[39] Moscow Radio, 2200 GMT, November 26, 1967.
[40] TASS, 1964 GMT, June 5, 1970.
[41] Pravda Ukrainy, Kiev, June 23, 1970, p. 4.

Vladimir Komarov serve as a relay point on Earth, with a further relay from the ship via one of the Molniya 1 satellites which shares mutual visibility between the ship and the Soviet Union. This type of relay was first mentioned in connection with the Soyuz 6–7–8 flights of October 1969.[42]

2. Akademik Sergey Korolev

On December 26, 1970, the Soviet Union announced the addition to the fleet of the Soviet Academy of Sciences the space satellite control ship *Akademik Sergey Korolev*. It was described as the largest scientific research ship in the world, 182 meters long and displacing 21,250 metric tons. It was not further described, but was to set out on its maiden voyage early in 1971.[43] Details finally were forthcoming in September 1971. It was described as a Diesel-engined ship with single propeller, a speed of 17.5 knots, and carrying a crew of 300. It had a radome just aft of the bridge, and two fairly large parabolic dish antennas, one amidships, and the other near the stern. The ship was described as having 28 suites of office, bedroom and bath for senior command staff, 34 single and 124 double cabins for crew and scientists. There was a gymnasium, two swimming pools (one enclosed), a library, reading room, and other cultural amenities. The ship had over 80 laboratories and dual air conditioning systems. The ship was active in the flights of Soyuz 10 and 11 serving as a link with Moscow via a Molniya satellite. It was built at Nikolayev on the Black Sea. With a range of 22,500 nautical miles, it was capable of 120 days of independent navigation without replenishment.[44]

3. Kosmonavt Yuriy Gagarin

This vessel was the latest and also the largest, most ambitious of the Soviet tracking ships. The ship made its first voyage in 1971. It looks as if it had been converted from the hull of a super tanker. The first account spoke of its having over 120 laboratories. Its scientific instrumentation came direct from scientific institutes rather than from industrial enterprises, and units were designed for easy installation and replacement so that the ship could keep up to date as technology advanced. It was designed to operate away from home base for as long as six months at a time. It had a 19,000 horsepower turbine power plant. The library had 10,000 books. Its theater seated 300 people. There were nine elevators, three swimming pools, and a sports hall big enough for a football match. There was also an automatic telephone exchange.[45]

The ship was described as having over 100 antennas, and via Molniya satellites could reach almost any telephone in the Soviet Union around the clock. It was capable of receiving high data rates from satellites and amplifying weak signals at planetary distances. There were over 1,250 compartments in the ship.

The *Kosmonavt Yuriy Gagarin* has a displacement of 45,000 tons, a speed of 18 knots, has a length of 231 meters, and a width of 31 meters.[46]

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[42] Izvestiya, Moscow, October 19, 1969, p. 2.
[43] TASS, 1817 GMT, December 26, 1970.
[44] Kamenetskiy, Yu. T. G. M. Balabayev, and O. M. Zlatopol'skaya "Akademik Sergey Korolev—A New Scientific Research Ship", Sudostroyeniye, Leningrad, No. 9, 1971, pp. 3–4.
[45] Leningradskaya Pravda, Leningrad, July 17, 1971, p. 1.
[46] Izvestiya, Moscow, July 18, 1971, p. 3.

Late in December 1971, a photograph appeared showing this ship anchored in Odessa, getting ready for its first operations. The first big dish antenna just behind the bridge was like a regular Orbita antenna for communication with Molniya. One of similar size was appearently intended to make trajectory and orbital data measurements. The two largest dishes, further back were intended for deep space work. In the same photograph were the 17,500 ton *Kosmonavt Vladimir Komarov* and the almost 21,500 ton *Akademik Sergey Korolev*. An accompanying article noted the new ship had 11 decks, and spoke of its many marvels, including a precision navigation system which permitted the antenna to correct for movements of the ship, movements of star fields, and also correct for angles of list and yaw in relation to the ship's course, and even for distortions in the ship's hull caused by heavy seas. This ship is also air conditioned throughout. Slightly different statistics credited it with eight elevators and 260 seats in its theater.[47]

Still another account counted 130 antennas in addition to the four main dishes. The ship's horsepower was listed as 19,500. It also has roll dampers and two maneuvering rudders in the bow and a third in the stern.[48]

The major antennas were listed as ranging from 12 meters to 25 meters in diameter.[49]

The new tracking ships were a great advance over such vessels as the *Ilichevsk* and *Krasnodar*, used for space support in 1957 and long since disappeared.

Table 1–12, which follows, summarizes what is known from public sources about all the Soviet tracking ships.

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[47] Izvestiya, Moscow, December 15, 1971, p. 4.

[48] Trud, Moscow, December 14, 1971, p. 2 ; Krasnaya Zvezda, Moscow, December 15, 1971, p. 4.

[49] Leningradskaya Pravda, Leningrad, March 15, 1975, p. 4.

TABLE 1-12.—CHARACTERISTICS OF KNOWN SOVIET SPACE AND MISSILE MONITORING AND CONTROL SHIPS

Name	Category	Displacement	Gross tonnage	Speed (kts)	Length (m)	Width (m)	Class and builder
Akademik Sergey Korolev	Civil	21,465	17,114	17.5	182	25	———, Nikolayev, U.S.S.R.
Aksay *	do		3,359	13.5	105	15	Tanker, Rauma, Finland.
Apsheron	Military		4,896	14.5	122	17	Vostok timber carrier, Leningrad, U.S.S.R.
Baskunchak	do		4,896	14.5	122	17	Vostok timber carrier, Leningrad, U.S.S.R.
Bezhitsa	Civil		11,089	16.0	156	21	Poltava cargo ship, Kherson, U.S.S.R.
Borovichi	do		5,276	15.0	122	17	Vostok timber carrier, Leningrad, U.S.S.R.
Chazma	Military	14,065		18.0	140	18	Dzanskoy cargo ship, ———
Chukhotka	do	5,000	3,800	15.0	108	13	Bulk ore carrier, Gdansk, Poland.
Chumikan	do	14,065		18.0	140	18	Dzanskoy cargo ship, ———.
Dauriya	do		4,896	14.5	122	17	Vostok timber carrier, Leningrad, U.S.S.R.
Dikson	do		4,896	14.5	122	17	Vostok timber carrier, Leningrad, U.S.S.R.
Dolinsk	Civil		5,419	14.5	139	18	Arkhangelsk, Abo, Finland.
Donbass	Military		4,896	14.5	122	17	Vostok timber carrier, Leningrad, U.S.S.R.
Ilichevsk *	Civil		4,459	11.0	117	16	Voroshilov, Haverton Hill, England.
Kegostrov	do		5,277	15.0	122	17	Vostok timber carrier, Leningrad, U.S.S.R.
Kosmonavt Vladimir Komarov	do	17,500	13,935	17.5	156	23	Poltava cargo ship, Nikolayev, U.S.S.R.
Kosmonavt Yuriy Gagarin	do	45,000	32,291	17.0	231	31	Sofia oil tanker, Leningrad, U.S.S.R.
Krasnodar *	do		6,001	10.0	121	16	Empire Dart, Malmo, Sweden.
Morzhovets	do		5,277	15.0	122	17	Vostok timber carrier, Leningrad, U.S.S.R.
Nevel	do		5,277	15.0	122	17	Vostok timber carrier, Leningrad, U.S.S.R.
Ristna	do		3,736	14.0	106	15	Neptun timber carrier, Rostok, G.D.R.
Sakhalin	Military	5,000	3,767	15.0	108	13	Bulk ore carrier, Gdansk, Poland.
Sevan	do		4,896	14.5	122	17	Vostok timber carrier, Leningrad, U.S.S.R.
Sibir	do	5,000	3,767	15.0	108	13	Bulk ore carrier, Gdansk, Poland.
Sutchan	do	5,000	3,710	15.0	108	13	Bulk ore carrier, Gdansk, Poland.
Taman	do		4,896	14.5	122	17	Vostok timber carrier, Leningrad, U.S.S.R.
Yamal	do		4,896	14.5	122	17	Vostok timber carrier, Leningrad, U.S.S.R.

* Withdrawn from this service.

NOTES

1. Data in this table are not wholly reliable because of differences among the sources used, but they are generally indicative.
2. The list shows alphabetically both civilian (Soviet Academy of Sciences) and military (Soviet Navy or possibly Soviet Strategic Rocket Forces) ships.
3. Displacements are presumably the full load displacement in metric tons.
4. Gross tonnage is typically a merchant or ex-merchant ship type of measure used for registry purposes and includes all permanently enclosed space in a ship less certain technical exceptions, measured in units of 100 cubic feet each; it is not a measure of weight.
5. Estimates of speed, length and width (in knots, meters, and meters, respectively) differ among sources and hence are not definitive.
6. Where known, the type of ship hull or former name and the city of construction are indicated.

SOURCES: Jane's All the World's Warships; Talbott-Booth Warship Identification, 1971; Talbott-Booth, Ship Identification, Part I, Merchant Ships, 1969; Lloyd's Register of Shipping; ——— (anonymous Commander, Royal Naval Reserve), Soviet Merchant Ships, 1945–1968, Kenneth Mason, 1969; Weyer's Warships of the World, by Gerhard Albrecht, U.S. Naval Institute, 1969.

4. Other Tracking Ships

It will be noted from Table 11 that four military tracking ships are relatively small, the *Sibir*, *Suchan*, and *Sakhalin* entered service first, The *Chukhotka*, *Chazma*, and *Chumikan* followed with the latter two being larger and faster. It probably was not coincidence that during the recovery of the aborted Apollo 13 flight the *Chumikan* was in this remote part of the South Pacific, not near known Soviet test areas, when it offered assistance to the Americans. Undoubtedly its reason for being there was the collection of intelligence by studying the Apollo reentry ablation phase.

Other tracking ships which have broken into the news, include the *Morzhovets* which was put under temporary arrest in a Brazilian port for violating territorial waters. During the Soyuz 9 mission, Trud reported that the *Morzhovets*, *Kegostrov*, and *Bezhitsa* were in the South Atlantic.[50]

During the Zond circumlunar flights, the Russians have described how they deliberately plan for these to approach Earth over the polar regions, sometimes dipping into the atmosphere and then skipping out again before making a second reentry and landing. In one case, Zond 5 entered over Antarctica, but instead of developing aerodynamic lift to skip out of the atmosphere and home to the U.S.S.R., it made a ballistic reentry and landed in the ocean. The Russians had named five tracking ships as being in that ocean, and it was the *Borovichiy* that made the pick up, but the capsule was transferred to a Soviet meteorlogical service ship, the *Vasiliy Golovnin* for carriage to Bombay, from where it was air-lifted home. Zond 8 also landed in the Indian Ocean, after a northern approach, but the ship making the pickup was not named.

Closely related to the Soviet Academy of Sciences ships like the *Morzohovets* and its three sisters are eight ships with naval crews that are not known to have supported the space program but apparently work on missile programs.

5. General Locations of Soviet Tracking Ships

The foregoing paragraphs have referenced several of the places where Soviet tracking ships can be found during missions, but a comprehensive summary of these locations was prepared by James E. Oberg of the United States.[51] Captain Oberg mapped in relation to spacecraft ground traces the favorite places for the tracking ships. For example, he showed that during most of the Soyuz flights, one of the high capacity civilian ships anchors off Sable Island, Nova Scotia (about 44.5° N, 59.5° W) where four successive orbits pass within easy direct communication range. A second location connected with the manned flights is in the Gulf of Guinea, West Africa, to monitor retrofire just before the reentry and landing near Karaganda in the U.S.S.R. In this same Gulf of Guinea area, deep space flights get their acceleration out of Earth orbit, so are often monitored there. When a deep space flight occurs, the ground trace reflects the combined effects of the acceleration to escape and the turning of the Earth itself. The ground trace goes east over Africa, Asia, and the Pacific, but as it climbs away from Earth, velocity is lost and the ground trace makes a

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[50] Trud, Moscow, June 6, 1970, p. 4.

[51] Oberg, James, Soviet tracking from the sea, Flight International, London, November 15, 1973, pp. 828–9.

U-turn over the South Atlantic and heads west over Central America. Hence, there are often tracking ships strung along this South Atlantic trace which otherwise would be unobservable with ease from Soviet territory. Finally, the Zond type of low G reentry from the Moon requires monitoring and potential pickup near Madagascar in the Indian Ocean when flights approach Earth over Antarctica. They also must be in the Indian Ocean between South Africa and Australia when such flights come in over the Arctic and land in the Indian Ocean. A large tracking ship either in a Cuban port such as Havana or Santiago, or in Trinidad gives added coverage to these deep space flights during early critical phases of the escape mission. During the ASTP mission, a large tracking ship was located off the coast of Honduras (at approximately 16° N, 87.5° W) to supplement the Sable Island position.

E. DEEP SPACE TRACKING

Reference has already been made to sea-based tracking in support not only of Earth orbital missions, but deep space flights as well. In the case of the United States, NASA saw a need for 24-hour worldwide coverage to support its deep space operations. It first built 25.9-meter steerable dishes at Goldstone, California, and in Australia, South Africa, and Spain, and these were followed by 64-meter dishes for Goldstone, Australia, and Spain.

The Soviet Union could profit from a similar worldwide capability, but has not achieved the same level of coverage. Its equivalent of Goldstone is at Yevpatoriya in the Crimea, once visited by Sir Bernard Lovell of British Jodrell Bank fame. The design approach used by the Russians has been different from the American approach. They seem to have two principal sets of antennas, each consisting of a single steerable mount carrying eight medium sized dishes arranged in banks of four. By operating these mounts along a railroad track, they can serve as interferometers. One would think it logical that there be a second installation in the Soviet Far East to expand their coverage, but if there is such a major station, it has not been revealed.

Beyond that, they rely on such devices as the three largest of their tracking ships which may take turns serving in the Caribbean area to extend Soviet deep space coverage. The only other Soviet recourse is to rely upon automatic systems in their deep space craft, or if more nearly real time data and commands must be exchanged, to plan their missions to have crucial events take place when that part of the world containing the U.S.S.R. faces toward the distant spacecraft.

F. SPACE OPERATIONS AND DATA PROCESSING CENTERS

Early Soviet pictures of space operations centers looked very simple by U.S. standards, but gradually over time, the pictures have shown advances in the kind of equipment the Russians have available. The program was about ten years old before detailed descriptions of control centers began to appear, and it was only with the Apollo-Soyuz Test Project that visits by Americans were permitted to one center.

Colonel General Tolubko described for TASS in November 1967 the role of the military in the launch of Venera 4, which can probably be assumed to be typical of so-called scientific flights. Members of the

Soviet Strategic Rocket Force conducted the launch, and ten minutes after lift-off, control passed from the military to the command measuring complex of stations all over the U.S.S.R. and on ships in several oceans.[52] That same month, Lieutenant General Leontyev stated that the Strategic Rocket Forces had been responsible for all launches of Sputniks, Lunas, Veneras, Molniyas, and the manned flights.[53]

In May 1968, *Red Star* described the computing-coordinating center (KVTS) operated by the Soviet Academy of Sciences. This center collects data from stations all over the world where it is then processed, analyzed, evaluated, and compared. *Red Star* described the center as having a huge operations hall, with a large map of the world at one end on which the computed trajectories of the current spacecraft were displayed. Illuminated panels either side of the main map carry the principal steps of the launch count down, and a status board of all other active Soviet payloads. Other walls are covered with more detailed diagrams, tables, graphs, and maps needed for the operation. The account went on to describe the receipt and use of many channels of telemetry.[54]

Pravda carried a further description in April 1969. This was in connection with the Venera flights. A side room was used for this purpose rather than the main hall. There were special telephones and apparatus for communicating with all computer coordinating centers and telemetry collection points throughout the U.S.S.R. Data on the flight position of the two Venera spacecraft then in flight were being plotted on a cylindrical recorder by tracing pens. In the telemetry section near by, the reporter saw more tracing pens plotting data from the spacecraft on paper bands. At the opposite end of the establishment were the big computers with the output unit passing out endless columns of numbers. In the main hall, primary data on the flight were being displayed on several large screens. The pictures were being drawn in full color diagrams by connection with a computer which was generating these displays directly from the telemetry.[55] This general description is highly reminiscent of the most advanced U.S. display systems.

More descriptions were released in June 1970. The reporter from *Izvestiya* reported that on the approach drive to the center he saw three large steerable antenna dishes which were receiving data. On this occasion it was Soyuz 9, and as soon as the ship came over the horizon, the large display screens showed live television from the cabin of the manned craft. He reported the tape was almost half a meter wide, as it poured out of a computer with many blinking lights.[56]

A similar article in *Krasnaya Zvezda* discussed the problems of command and control during flights, recommending a combination of commands sent to the spacecraft by radio from Earth, and others program-timed on board the spacecraft itself. The report mentioned that the deep space flights launched from Earth orbit are observed by radio and sent command signals from ships placed in the Atlantic and Mediterranean, which is consistent with our knowledge that the probe

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[52] TASS, 0738 GMT, November 16, 1967.
[53] Trud, Moscow, November 19, 1967, p. 1A.
[54] Red Star, Moscow, May 16, 1968, p. 4.
[55] Pravda, Moscow, April 12, 1969, p. 6.
[56] Izvestiya, Moscow, June 4, 1970, pp. 1, 4.

or escape rocket is generally fired somewhere over or near Africa. Other flights are supported by aircraft, particularly during the recovery phase, supplementing the ships used for search, rescue, and evacuation of spacecraft which have landed in ocean areas. Information from all these sources feeds into the ground complex. The total combination of all support aids involves systems for orbital path measurements, reception and registry of telemetry, controlling onboard instrumentation, communications, and a standard time service. Communications may be relayed through Molniya satellites, and reliance is placed on the Meteor satellites for supporting weather data.[57]

Communications in near-Earth space require a greater number of antennas, but those for flights to lunar and planetary distances need special, large antenna systems, special molecular and parametric amplifiers, and special narrow band filters to sort out weak signals amidst space "noise". At least two but not more than four deep space stations if sufficiently spread out, are all that are needed for planetary flights.[58]

Still another account in *Pravda* described the antennas as 25 meters in diameter at the main space flight control center. The main receiving antenna is close to the buildings of the center. The transmitting antenna to the spacecraft is about ten kilometers away. Because several different frequencies are used, and these pass through the receiving antenna, special devices sort them out to deliver the separate components of television, telemetry, and telephonic information. These are all recorded on magnetic tape, while the information on orbital information especially is fed immediately to the computers. When commands are sent to the spacecraft, these are in coded form which has been put into the computers, so that only pressing a button on a panel is required. When these signals are played back to Earth correctly from the spacecraft, only then does the "execute" command go out to the spaceship.[59]

It was interesting that through all these years of partial disclosure, there was never a clue as to the location of the space control centers. Certainly the launch itself is controlled by military men at the individual launch sites. It was this immediate block house with its periscopes that was declared off limits when American astronauts, technicians, and other higher officials visited Tyuratam in connection with the Apollo Soyuz mission.

When the Apollo Soyuz mission was approaching, the Russians opened up some more information by making known they were building an entirely new space control center for this mission in the general vicinity of Moscow. It was revealed that the Soyuz 12 flight was the first one controlled from this new center northeast of Moscow.[60] At first the site was believed to be at Kalinin, 150 kilometers northwest of Moscow. But the site was finally located accurately when the U.S. press representatives were allowed to visit it in mid-May 1975. It was in Kaliningrad, 10 kilometers northeast of Moscow and 10 kilometers northwest of the Yuriy Gagarin Cosmonaut Training Center at Zvezdny Gorodok.[61] It had been building since 1970. The main opera-

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[57] Dmitriyev, G. Eyes and ears of the Earth. Krasnaya Zvezda, Moscow. June 12, 1970, p. 2.
[58] Idem.
[59] Smirnov, V. Information from orbit, Pravda. Moscow, June 9, 1970.
[60] Aviation Week, New York. November 5, 1973, p. 20.
[61] Soviet Aerospace, Washington, May 19, 1975, p. 18.

tions room has five banks of consoles, 24 in total with a large screen map of the world in front center, with the orbital path and all tracking stations shown on the map, with additional data listed on side panels. It was evident from these disclosures that there must be a different and possibly more versatile center already in use elsewhere. The Russians were evasive on this point, but during the Apollo Soyuz mission mentioned almost casually that the Salyut mission was being controlled from a center at Yevpatoriya, the same site in the Crimea where the deep space tracking station is located. Whether there are still other major control centers is not known. It is reminiscent of the fact the United States has control facilities at each of its major launch sites in Florida and California, and also has additional facilities in Houston, Texas; Greenbelt, Maryland; and Sunnyvale, California at the very least. So for some purposes, the Russians may also have additional locations in use.

G. SPACE RESEARCH CENTERS

Reliable information about Soviet space research centers is also limited. There are a few which have come to public attention. For example, the engine development work of the Leningrad Gas Dynamics Laboratory has been revealed through research publications of a theoretical nature, and early experimental engines as well as a few currently operational engines have been put on display and described as developed there. There is even a museum in Leningrad where it is possible to see these products.

The large body of published literature in various fields of space sciences reveals researchers in many scientific institutes pursue studies of geophysics, the upper atmosphere, radiation, space medicine, the planets, the Sun, and so forth. But it is not possible from these papers to build a definitive list of titles and locations of space laboratories and centers. It can be assumed that some are in the new science cities which have been created in several parts of the Soviet Union.

A fairly detailed description of one major institute was provided during 1971. The Moscow Space Research Institute of the Soviet Academy of Sciences consists of administrative buildings, parking lots, and landscaping in front, and laboratories in the central area, with experimental and storage areas at the back. The administrative building has three stories, underground parking, a library, conference and reception rooms, and an auditorium seating 1,200 persons. The laboratories are in a 13-story building with 2-story annexes. There are special air-conditioning units in towers nearby. All told, there are 41,000 square meters of floor space, including 33,000 square meters in laboratories; and the building volume is 599,870 cubic meters, including 534,700 cubic meters in laboratories.[62]

H. MANUFACTURING AND ASSEMBLY CENTERS FOR SPACECRAFT AND ROCKETS

Few details are available on Soviet factories equivalent to those of American industry in which specialized craft are built or where "serial" production is carried on. Occasional American visitors have

[62] Stroitelstvo i Arkhitektura, Moskvy, Moscow, No. 1, 1971, pp. 26–29.

been allowed to visit aircraft factories, and it is always possible that some space manufacturing is done in closed but adjacent buildings in some of these aviation centers. Occasional photographs have shown assembly lines for Vostok and for Soyuz spacecraft, and the numbers of such craft shown in the pictures strengthens the notion that the same basic shells are used for the large unmanned recoverable Kosmos flights used by the Soviet military to conduct observations of interest. Somewhere there must also be a production line for the smaller Kosmos, because many use the same basic shell, with modifications to fit the particular missions of the craft.

Except for the very largest launch vehicles, presumably almost all components are rail-transportable, especially as the Soviet railway lines have a generous clearance gauge through tunnels and stations. We know both through Soviet movies and through the recent visits to Tyuratam that launch rockets and payloads are brought together in assembly buildings within a few kilometers of the launch pads, with the mating done horizontally, and then the combined rocket and payload pushed out to the pad atop flat cars and special transporters by Diesel locomotives. At the pad, the transporter tilts the rocket up into a vertical position for final checkout and launch. This may not be true of the G–1–e class vehicles, but seems to apply even through the D–1–e class.

I. TEST AND TRAINING CENTERS FOR SPACE

Of necessity the Russians must have test stands for rocket development, and environmental chambers for rockets and payloads. These are not described as to location in the open literature.

Because of the numerous Soviet failures in planetary payloads, they have come to the American practice of having a duplicate payload in an environmental chamber undergoing as nearly as possible the same conditions as the actual spacecraft in flight, so that if problems develop, solutions can be tested with the laboratory "bird". This was first announced as the practice with the Venera 4 flight.[63] Something similar has been hinted at in connection with manned flights in 1974 and 1975.

The principal test and training center for Soviet cosmonauts is at Zvezdnyy Gorodok east of Moscow in the suburbs. This has been visited by both the American astronauts and NASA technicians, and also by the Western press. There are classrooms, isolation chambers, centrifuges, simulators, and mockups, as well as good living accommodations for the cosmonauts and their families, and associated scientists and technicians.

Apparently there are some facilities for training in the Tyuratam area, presumably in or near the new, burgeoning city of Leninsk. The American visitors found the accommodations provided at Leninsk to be equal or superior to those provided at the Kennedy Space Center. The cosmonauts when suited up for flights ride out to the pad in a well equipped, air conditioned bus, much in the manner that NASA astronauts are transported.

When the Soyuz 9 cosmonauts returned to Earth, they went to a special isolation center, which was highly reminiscent of the Houston quarantine facility, perhaps as a dry run for similar procedures once Soviet cosmonauts return from the Moon.[64]

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[63] Tass, 0800 GMT, October 19, 1967, quoting Komsomolskaya Pravda, Moscow.
[64] TASS, 1704 GMT, June 20, 1970.

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The lunar material recovered by Luna 16 on the Moon was also taken to a special isolation laboratory at an unspecified point which employs the same general kind of procedures to preserve freedom from contamination, both in and out, as Houston has supplied for its Lunar Receiving Laboratory.[65]

All in all, one is struck with the close parallels between the U.S. and Soviet programs in terms of procedures and equipment, but also with the paucity of definitive Soviet information in the public domain on any of these matters aside from the few facilities which have been occasionally opened to visitors.

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[65] TASS, 1077 GMT, September 26, 1970.

CHAPTER TWO

PROGRAM DETAILS OF UNMANNED FLIGHTS

By Charles S. Sheldon II*

I. Early Years

Although it is the mission of this report to concentrate primarily on Soviet space developments from 1971 to 1975, it seems desirable to supply enough of the earlier history of the Soviet program to provide continuity and perspective, and to provide accessible information for those who do not have copies of similar reports covering in detail the earlier years of the Soviet program.

A. ORIGINS OF THE SOVIET SPACE PROGRAM

1. Early Interest

Other sources have traced the evolution over the centuries of man's interest in the universe beyond his Earth and his gradual recognition of the nature of the problems to be overcome in entering this larger environment and how this might be accomplished within the bounds of human science and engineering.[1]

A quasi-scientific description of solutions was provided by such writers of a century ago as Jules Verne in France[2] and Edward Everett Hale in the United States,[3] using the medium of fiction. In the first quarter of the present century, three outstanding scholars analyzed and experimented with rockets and space techniques to merit the labels of fathers of modern space programs. These were Robert H. Goddard in the United States, Hermann Oberth of Germany and central Europe, and Konstantin Tsiolkovskiy of Russia.

Of these three, Tsiolkovskiy was probably the first to receive widespread and official recognition for this genius, and chronologically, his work predates that of the other two men, although language and cultural barriers meant the writings of Tsiolkovskiy had little impact outside what is now the Soviet Union. Today he continues to be a national hero in his home country. The Tsiolkovskiy medal is awarded for outstanding contributions to space progress, and the home town of Kaluga where Tsiolkovskiy lived and worked has a space museum.

By the 1930's, private societies in a number of countries, especially in the U.S.S.R. (GIRD—Gruppa Isutcheniya Reaktivnovo Dvisheniya), Germany (VfR—Verein für Raumschiffahrt), Britain (BIS—British

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[1] Von Braun, Wernher and Ordway, Frederick I., III, History of Rocketry and Space Travel. New York: Crowell, 1966; Ley, Willy. Rockets, Missiles, and Space Travel. New York: Viking Press, 1958: Emme, Eugene M., History of Space Flight. New York: Holt, Rinehart, and Winston, 1965.

[2] Verne, Jules, From the Earth to the Moon, 1865; Round the Moon, 1870.

[3] Hale, Edward Everett, The Brick Moon, Atlantic Monthly, November 1869–February 1870.

Interplanetary Society), and the United States (ARS—American Rocket Society) were experimenting with rockets, and writing papers on space travel. The most aggressive support and conversion of rocket work to meet practical applications came in Germany where the Army appointed Captain Dr. (and later Major General) Walter Dornberger to head this effort. From the VfR, he drew interested technical support, and his young chief engineer was Dr. Wernher von Braun.[4] It was this team which eventually produced the V–2 rocket of World War II, the vehicle which also became the first significant tool for exoatmospheric research in the United States, the Soviet Union, France, and the United Kingdom. Modifications of the V–2 especially were important to early Soviet military missilery, while several U.S. rocket systems clearly show the same ancestry.

Dr. Dornberger, Dr. von Braun, and several hundred of the top rocket engineers of the German program came voluntarily to the advancing U.S. forces in Europe, or were acquired at the end of the war under Operation Paper Clip. Soviet forces, meanwhile, overran the principal test station on the Baltic at Peenemünde, and later, underground factories in Silesia. They picked up more hardware and test equipment, and some technicians, but fewer of the top group of engineers. The Western allies also acquired in territories they overran, near the English Channel, complete and partially assembled V–2's which they stockpiled for experimental use. Apparently the Soviet Union in the postwar years resumed serial production of the V–2.

It should be emphasized that the Soviet Union had a strong rocket program of its own well before any technology was picked up from Germany. No nation made more effective use of tactical rockets in combat during World War II than the U.S.S.R. Also, there is an extensive technical literature throughout the 1930's largely coming from the Gas Dynamics Laboratory in Leningrad in support of understanding rocketry.

The United States had its own rocket efforts in the Army and Navy, and later the Air Force, with such outstanding centers of effort as the Jet Propulsion Laboratory in Pasadena and the Naval Ordnance Test Station, China Lake, California. The German Paper Clip scientists were first at Fort Bliss, Texas, and later at Redstone Arsenal in Huntsville, Alabama. Other work was pursued in private industry under Government contract.

The full details of the corresponding Soviet effort are obscured by their penchant for secrecy, but the broad outlines have been revealed in summary histories. One can sense the barest beginnings of an international competition in the early years after World War II. From the debriefings of Dr. Wernher von Braun, the United States was presented with fresh ideas on how rockets could be made to fly across the Atlantic Ocean carrying weapons, although Dr. Vannevar Bush was able to point out a number of reasons why the concept was impractical at that time.[5] The Germans also described permanent manned space stations in Earth orbit serving a variety of scientific and military purposes. These plans were brought to public attention in understand-

[4] Dornberger, Walter, V–2, New York: Viking Press, 1954.

[5] Emme, Eugene M., Op. Cit, p. 108: Dr. Bush testified before Congress in about 1947: "[An intercontinental ballistic missile] is impossible and will be impossible for many years to come. I think we can leave that out of our thinking. I wish the American public would leave that out of their thinking."

able form by such means as illustrated articles in *Collier's* magazine in the early 1950's. By this same time, the world community of engineers interested in space had organized the International Astronautical Federation (IAF) and at its meeting came the first reports that the Soviet Union was designing orbital spacecraft, and even was planning a very large ship to carry men to the Moon. In the United States by the end of the 1940's, rival projects at the study level were underway to explore construction of satellites for military purposes in all three of the armed services. These plans did not proceed beyond the study phase, and indeed, conservative elements of Government and the military greatly restricted discussion of spaceflight lest the Congress react negatively to such "foolishness". Although the Soviet Union was relatively quiet in any public statements, it seems to have accepted at a high level of Government at a much earlier stage that space could be a practical endeavor worth supporting.

2. Organization of the Soviet Effort for Space

Another portion of this report will treat organizational matters in greater detail. It suffices here to note how, well after the fact, it has come to Western attention that the Soviet Union in about 1953 created a permanent Commission on Interplanetary Travel, its nearest early equivalent to the United States NASA of 1958. Although the details are lacking, it seems almost certain that within a year of that organization, the broad outlines of the Soviet space program which were pursued for at least the next five to eight years were mapped out. A clear decision was made to apply military technology to the development of space.

3. Soviet Weapons Planning

One will recall that at the end of World War II, the United States was at the peak of its military power compared with much of the rest of the world. Although we rapidly dismantled much of this force and shut down military bases, we relied upon our nuclear capability, then close to a monopoly, to serve as an airborne strategic deterrent as a means for maintaining peace in the world, at least to the extent of avoiding general war. The Soviet Union, by contrast, faced great devastation at home, had a large army which was only in the process of moving from animal power transport and foraging the countryside for logistics purposes, to reequipping with motorized transport. It had a tactical air force, but was weak in strategic bombers. It had a defensive navy with heavy emphasis on coastal submarines, and no aircraft carriers to extend air power as did the United States.

The Soviet Union seems to have made the deliberate decision to move aggressively into the new technology of rocketry, even in advance of its development of nuclear weapons appropriate to long range delivery by rockets. While the United States had considered a number of ballistic rocket designs, it first put greater stress in the missile area on automatic pilotless aircraft. Its principal design for an ICBM would have been a very large rocket before the thermonuclear breakthrough.[6] Once the more powerful warheads of reasonable size could be counted on, our designs for Atlas and then for Titan were scaled down to a more economical set of dimensions.

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[6] Stine, G. Harry, How the Soviets did it in space. Analog, New York, August 1968, p. 66.

But the Soviet Union, despite its approximately parallel development of fusion weapons, seems already to have committed itself to a very large ICBM. This weapon, developed through the middle 1950's, would be considered in this country as oversized for ease of operations and economy, and awkward because of reliance on cryogenic oxidizer and radio guidance during launch. It has now been replaced in the military arsenals by a number of much more effective weapons of simpler design, storable fuel, and inertial guidance. But the original ICBM to this day remains the very effective mainstay of the Soviet space launch vehicle stable. This vehicle by Soviet claim made its first flight on August 3, 1957 from Tyuratam toward the Kamchatka peninsula. The same launch site was then readied for the Sputniks to follow.

4. Plans for the International Geophysical Year

After the exciting but perhaps premature plans for manned Moon rockets and Earth orbital stations, revealed in *Collier's* and elsewhere in the early 1950's, U.S. thinking on space retreated to some fairly modest proposals for launching small unmanned satellites for scientific purposes. Agreement was won in 1955 that the Federal Government would support the IGY by funding a non-military launch vehicle to put up a few pounds of instrumentation. Although the Redstone military rocket built by the von Braun Redstone Arsenal team and carrying experiments of the Jet Propulsion Laboratory and the University of Iowa was a possibility, President Eisenhower was advised and agreed to support a new effort by civilian scientists of the Naval Research Laboratory and an industry team to build Vanguard. The President announced the IGY satellite program on July 29, 1955. A day later, the Soviet Union announced that it, too, planned to launch scientific satellites during the IGY period, although the specifics were not then made available.

With the advantage of hindsight, it is possible to see that by 1957, the Russians were telling the world that its satellites might be somewhat larger than the 9 kilogram planned payload of Vanguard, and as early as June 1957, that the radio frequencies to be used by their craft would not be those which were recommended for IGY purposes, but in a high frequency range readily receivable by radio amateurs.

B. THE FIRST SPUTNIKS

1. Sputnik 1

Rumors of an impending launch, perhaps in time to celebrate Tsiolkovskiy's birthday on September 17, 1957, began to circulate in Moscow. Although this did not happen, the rumors grew more positive in the first week of October. Even so, the Sputnik shock of October 4 has become a classic case. Not only laymen, but many technical people were caught by surprise with the Soviet announcement of the first satellite. Launched from an unspecified point, it circled the Earth every 96 minutes at an inclination of 65 degrees to the Equator, which meant it passed overhead of most of the inhabited world. It broadcast on two harmonic frequencies close to 20 and 40 megahertz. Battery powered, variations of its cricket-like beeping signal both revealed characteristics of the ionosphere and told of its own temperature changes. Its variations in orbit and eventual decay revealed something of atmospheric density. But its announced weight of 83.6 kilograms, an order of magitude greater than the planned American satel-

lite, suggested to a number of scientists that a decimal place had been in error. There were still others who could not accept the notion the Soviet Union could be first in a field of advanced technology and they invented elaborate schemes for explaining Soviet trickery to simulate a satellite which they felt did not exist in fact. It also became popular to believe there were constant Soviet attempts to launch which generally failed, and that whatever had been put up was necessarily crude and only for propaganda purposes, and in any case was built by Germans or stolen from the United States. The assessments were wide of the mark.

2. Sputnik 2

While the first Soviet satellite was a bad shock, its simple structure, limited battery power, and lack of instrumentation, other than its beacons, could be contrasted with the more elaborate, miniaturized instrumentation promised for Vanguard. However, on November 3, 1957, the second Soviet payload placed in orbit was announced as weighing 508.3 kilograms, and it carried a respectable range of geophysical instrumentation. Also, it contained a life support system and returned biomedical data for a week from the dog, Layka. This supplied basic data for planned manned flights. The life support system showed it could function remotely. Data were returned on the effects of weightlessness and G load during launch, on radiation, and on temperature changes. Sensors measured some kinds of radiation and micrometeorite impacts. Also, the Russians revealed what was evident to visual observers: The payload remained attached to a much larger spent rocket casing, so that the total weight was probably on the order of 6.5 metric tons.

3. Sputnik 3

In the months which followed, the United States faced the frustrations of launch delays and launch failures, including the explosion of a Vanguard test vehicle on December 17, 1957, with the world press to witness the ball of fire at the launch pad. However, the revived Redstone Project Orbiter, which might have been launched even before Sputnik 1, met with success on January 31, 1958 (local time) to put up 14.5 kilograms of payload and rocket casing for Explorer 1. Also, Vanguard was later (March 17, 1958) successful in putting up a 1.4-kilogram test vehicle and a 23-kilogram rocket casing.

On May 15, 1958, the Soviet Union put up Sputnik 3, and it was by far the most formidable challenge to the U.S. program. It was a 1,327-kilogram orbiting geophysical observatory of considerable sophistication. Unlike the two battery-powered previous flights, this vehicle was equipped with solar cell panels, elaborate louvres for heat control, and an array of instrumentation which matched all the experiments planned for the U.S. IGY series of flights and also those planned for the immediate post-IGY period. Although this ship carried heavy, off-the-shelf conventional electronic equipment such as vacuum tubes, it also contained thousands of solid state devices. It was in effect the early equivalent of the American OGO flights of 1964 on, although with a lower data rate of return. It is to Soviet credit that the ship continued to operate electronically until the moments of its reentry and burning in the atmosphere two years after launch.

All three Soviet Sputniks placed their instruments in sealed containers which were maintained at normal Earth surface pressures and contained gas constituents of normal atmosphere. Although only Sputnik 2 had its carrier rocket final stage left attached to the payload, all three were put up by the same original ICBM system. The whole core vehicle was in orbit, with its weight of about 6 metric tons, measuring 28 meters long, slowly tumbling end over end, almost the size of a railway Pullman sleeper. It was this big rocket which was most easily identified on its passage across the night sky by observers in every continent.

C. THE FIRST LUNAS

1. Luna 1

At the close of 1958, Soviet authorities announced that the new year would bring the first Soviet flights to the Moon. On January 2, 1959, Luna 1 was launched on a fast flight toward the Moon, carrying a payload weight of 361.3 kilograms, plus a separated final stage carrier rocket with a weight of 1,111 kilograms, for a total weight of 1,472 kilograms, The payload had a minimum collection of geophysical instrumentation in a spherical container, and projecting antennas. Because of the high velocity and its announced package of various metallic emblems with the Soviet coat of arms, it is reasonable to conclude that it was intended to strike the Moon. It missed its target, and flew by the Moon at a distance of 5 to 6 thousand kilometers at nearest approach, had its orbit bent by lunar gravity and flew off to become the first artificial planetoid of the Sun. Its batteries gave out very soon after, on January 5, at 600 thousand kilometers from Earth. Yuriy Gagarin acknowledged its strike mission, in which it failed.[7]

The United States also was undertaking a lunar program in this same general period. The first three Pioneer flights in late 1958 were intended to orbit the Moon. The first was destroyed at the Cape during launch. The next two Pioneer flights developed insufficient velocity to reach the Moon, and fell back to Earth. The next two Pioneer flights used different hardware and were intended to make close passes by the Moon. The first fell back to Earth because of insufficient velocity. The second (called Pioneer 4), launched March 3, 1959, flew by the Moon at a distance of 60,000 kilometers. This 6 kilogram payload was battery-powered, and signals ceased at about 654,250 kilometers from Earth.

2. Luna 2

On September 12, 1959, a Soviet attempt to hit the Moon was launched again, and this time was successful in striking about 435 kilometers from the visible center of the Moon the following day.

3. Luna 3

A much more complex operation was launched on October 4, 1959. This payload, referred to as an Automatic Interplanetary Station, flew past the Moon at about 7 thousand kilometers, and then while in optical view of a good part of the never-before-seen far side of the Moon, it was stabilized, took a series of photographs which were developed on board, and the information was scanned to be radio-transmitted back to Earth in facsimile form. Because the payload was

[7] Reuters, Moscow, July 29, 1961, quoting his letter to the magazine, Soviet Lithuania.

equipped with solar cells, it had a much longer active life than its two Luna predecessors. Its so-called barycentric orbit brought it sweeping back toward Earth. The pictures were returned on October 18, and were to have been transmitted at another point much closer to Earth, but the second transmission was not accomplished. Typical of barycentric orbits which are influenced in a complex way by the tug of both Earth and Moon gravity, the flight path kept changing, and apparently after 198 days in eccentric orbit, the payload, long since radio-silent, reentered the Earth's atmosphere to burn. Its pictures were very indistinct, but through computer enhancement permitted the Russians to develop a tentative atlas of the far side of the Moon. Those individuals who charged this, too, was a Soviet forgery were proven wrong when some of the same features eventually were found in the later and far superior pictures taken by American Lunar Orbiter spacecraft. Lunar Orbiter 4 of August 1967 found the Tsiolokovskiy crater named in the Luna 3 pictures.

D. THE KORABL SPUTNIKS

Soviet visible space activity during 1960 was devoted to testing the precursors for their early manned flights. These are referenced here simply to maintain the chronology, and will be discussed in the following chapter on manned flights.

E. BEGINNINGS OF THE PLANETARY PROGRAM

1. 1960 Mars Attempts

The Soviet Union until recently had never admitted to any launch attempts which fell short of attaining Earth orbit. The United States in a number of instances has been able to monitor such failures, but on only one occasion has disclosed this knowledge officially (on September 5, 1962). On October 10, and again on October 14, 1960, the Soviet Union launched a new combination of rockets intended to send payloads to the vicinity of Mars, but neither was successful in reaching even Earth orbit. From their subsequent repetitive use of an orbital launch platform technique for planetary and other missions remote from low Earth orbit, we can imagine how the operation was intended to proceed.

People had been expecting a Soviet Mars attempt at the appropriate astronomical "window" for this launch. Premier Khrushchev timed his arrival in New York at the United Nations accordingly, expecting to be able to announce the flights. A seaman defector from the Soviet ship *Baltika*, which had brought Khrushchev told reporters that on board the ship was a replica of an advanced spacecraft which was to be put on display if a certain mission were successful. If true, the replica was carried back to the Soviet Union unseen.

2. 1961 Venus Attempts

On February 4, 1961, the Soviet Union announced the launch of Tyazheliy Sputnik 4, of 6,483 kilograms, described as a test of an Earth orbital platform from which an interplanetary probe could be launched. The fact that this launch occurred at the correct hour for a Venus probe indicated the mission while an Earth orbital success was a Venus probe failure. In this respect, a further evolution of Soviet technology was demonstrated. The first three Luna flights

had been direct ascent missions; probably starting in October 1960, the change to a more powerful upper stage occurred, and the added flexibility of launch from orbit was intended, an approach which has been used ever since for deep space missions. Another launch was announced on February 12, 1961—Tyazheliy Sputnik 5—and from this came a probe or Zond rocket carrying another Automatic Interplanetary Station (AIS) called Venera 1. The payload weighed 643.5 kilograms. It was by far the most elaborate payload combination to be unveiled to that time. For some weeks the mission went well, but at a distance of about 7.25 million kilometers from Earth, communications ceased. The payload is estimated to have passed Venus at a distance of about 100,000 kilometers on May 19, 1961, based on its known trajectory.

3. 1962 Venus Attempts

Venus launch windows come about every 19 months. True to practice, the Soviet Union launched multiple attempts on August 25, September 1 and September 12, 1962 carrying Venera spacecraft. All of these reached Earth orbit, but failed to launch their payloads successfully toward Venus, leaving various kinds of debris and major segments in Earth orbit. No Soviet acknowledgment of these launches has been made to this day. The United States routinely published its Goddard Satellite Situation Report including the August 25 pieces of debris in Earth orbit. But then it began to worry about the possible diplomatic consequences of such announcements, and for a time suspended publishing the statistical report altogether; and when it resumed, it skipped all Soviet objects in orbit after August 25, 1962. However, all objects, listed or not, are assigned a sequential astronomical designator which is supposed to account for all observable objects in orbit. The omission of certain designators signalled to anyone familiar with the system that there were unacknowledged flights in orbit. In early September, press accounts rumored that the United States had begun to make secret military launches, and the Soviet representatives at the United Nations made charges against the United States to this effect. Our representative denied this and said the stories "were not wholly accurate", rather than revealing there had been a Soviet launch on September 1. The diplomatic stances adopted by both countries are not too flattering to either, in retrospect. Actually, for a long time, the September 12 Soviet launch was carried in British publications as a secret U.S. launch because of the de facto U.S. and Soviet agreement not to disclose these Soviet failures.

4. 1962 Mars Attempts

The window for Mars flights comes about every 25 months, and Soviet launch attempts were made on October 24, November 1, and 4, 1962. All three reached Earth orbit; the first and third were never acknowledged by the Soviet Union because that is all they did. The flight of October 24 was especially awkward in its implications because it came at the time of the Cuban missile crisis, and it broke into a considerable number of pieces of debris which followed a path bringing these within view of the Alaska BMEWS missile detector system. The first impression might have been one of a massive missile attack against the United States, although the computer must have quickly revealed it was not.

The November 1 launch was the only success in launching a probe (Zond) rocket from the Earth orbiting platform in six 1962 attempts. The AIS (Automatic Interplanetary Station) received the name Mars 1. This payload set a record of active communications with Earth to a distance of about 106 million kilometers on March 21, 1963, after which signals ceased. The ship passed Mars at a distance of about 193,000 kilometers in June 1963. This payload had been improved over Venera 1 by raising its weight to 893.5 kilograms, and having a greatly improved "bus" for the instrumentation and more elaborate experiments. In fact, the basic design of this craft became the standard Zond payload for planetary missions as revealed through Zond 3 and Venera 8.

5. 1964 Venus Attempts

Since ten planetary attempts had succeeded in launching only two Zond payloads, and both of these had failed to continue communications all the way to their planetary destinations, it appears the Russians launched a diagnostic flight November 11, 1963, which was acknowledged as Kosmos 21, but it was not able to send a deep space Zond beyond Earth orbit.

Nonetheless when the Venus window came, a launch was made on March 27, 1964. When it failed to launch a Zond, it was given the name Kosmos 27, and was passed off as a routine flight. It will be noted that this was a change of information policy, compared with the 1962–63 period when debris in Earth orbit was not acknowledged. The United States, goaded by further Soviet charges at the United Nations about project Westford, space "needles", in its counter blast named the five 1962 planetary Zond failures which reached Earth orbit together with a 1963 Soviet Moon flight failure which also was stranded in Earth orbit. The closest thing to a Soviet acknowledgment was a Soviet further complaint that the United States was attempting to register flights of other nations, which was not its business under the registration agreement of the United Nations. In any case, by assigning an arbitrary and neutral Kosmos (Space) name and number to later escape failures stranded in Earth orbit, the Soviet Union thereafter avoided this particular information problem.

On April 2, 1964, another Venus probe was launched. Because of the poor record of its predecessors, the U.S.S.R. this time simply labeled it Zond 1. However, the details announced on its course made clear that it was bound for Venus. Communications failed soon after May 14, and it passed Venus on July 19, 1964 at 100,000 kilometer estimated distance.

6. 1964 Mars Attempts

The Soviet Union launched Zond 2 toward Mars on November 30, 1964, and this time acknowledged that it was bound for Mars, which would have been evident to Western astronomers and space trackers anyway. Communications failed some time in April 1965, but the Zond made a close pass by Mars at about 1,500 kilometers on August 6 of that year.

There was a strong likelihood that another Mars attempt was planned for the 1964 window because every other window to Mars and Venus from 1960 on had seen multiple Soviet attempts. It may be that

difficulties in the launch preparations delayed the flight beyond the window. In any case, it was not until July 18, 1965 that Zond 3 was launched on a trajectory which carried it all the way out to the orbit of Mars. But because the launch was made without reference to a suitable launch window for Mars, that planet was nowhere near the Zond when it achieved that distance. However, as a diagnostic test, Zond 3 also made a flyby of the Moon, passing it at a distance of about 9,200 kilometers. It took 25 pictures of the far side of a quality superior to those of Luna 3, and these were returned to Earth by facsimile a number of times at ever-greater distances, proving the ability of the communications system to do its planetary task. Some signals were still being received when Zond 3 reached the orbital path of Mars.

7. 1965 Venus Attempts

With renewed confidence in the basic Zond bus, the launch of November 12, 1965 was named Venera 2; that of November 16 was named Venera 3; but that of November 23 was only Kosmos 96, because it failed to launch its Zond from the Earth orbiting platform. Venera 2 passed Venus at a distance of about 24,000 kilometers on February 27, 1966. Venera 3 struck Venus on March 1, 1966 about 450 kilometers from the center of the visible disk. The Russians received many congratulations for these twin successes, which included sending the first manmade object to the surface of another planet. Soviet emblems were contained in the payload. A few days after the congratulations had been received, the U.S.S.R. revealed that communications had failed in both Zonds at an unspecified time shortly before the planet had been reached. This ran the total to 18 Zond payloads expended without a single bit of planetary data returned, although there were a number of engineering triumphs involved and some data on the interplanetary medium, as well as pictures of the Moon.

8. 1967 Venus Attempts

Venera 4 was launched on June 12, 1967, using an A–2–e vehicle like its predecessors, but carrying a heavier payload of 1,106 kilograms. Two days before arrival its mission was revealed as one to make direct atmospheric measurements. On October 18, 1967, a capsule separated from the bus, and after aerodynamic braking, the capsule deployed a parachute, on which it hung for about 1.5 Earth hours while descending toward the surface where it deposited the Soviet coat of arms marked on a pennant of metal, as had been true of Venera 3. Its successful return of planetary data was an important first in the Soviet program. Data were refined over a period of time, apparently suggesting some problems of calibration and interpretation. At first the Russians thought they had data readings all the way to the surface, but unless a landing had occurred on a very high mountain peak, it is more likely that signals ceased at an altitude of 25 kilometers. With this assumption the Soviet data could be reconciled with the indirect U.S. Mariner readings, which were based upon interpretations of radiated and reflected energy.

The main bus of the Soviet Venera 4 carried a magnetometer, cosmic ray counters, hydrogen and oxygen indicators, and charged particle traps. It found a weak hydrogen corona at 10,000 kilometers above the surface on the night side of Venus and a magnetic field only

0.001 the strength of that around Earth, and no radiation belts. The bus was burned as it plunged into the atmosphere.

The sterilized landing capsule was an egg-shaped package about one meter in diameter, weighing 383 kilograms and protected by ablative material against the high heat of entry friction. The parachute, deployed after the speed was slowed sufficiently, was made of heat resistant material. The capsule carried two thermometers, a barometer, a radio altimeter, an atmospheric density gauge, and 11 gas analyzers. The latter took 5 readings at an altitude of 25 kilometers and others at an altitude of 23 kilometers. Signals from the capsule were received for 96 minutes both in the U.S.S.R. and at Jodrell Bank. The readings received ranged from a first temperature of 39° C. to a final reading between 263 and 277° C. The atmosphere was measured as 90 to 95 percent carbon dioxide, 0.4 to 0.8 percent oxygen, perhaps between 0.1 and 0.7 percent, but not over 1.6 percent water vapor. The remainder might have been argon or other inert gases, and if nitrogen was present, it was not identified. The final pressure reading obtained was 15 to 22 times that of Earth. Later study by both American and Soviet scientists of the Soviet data suggested the Celsius temperature at the true surface was probably about double the reading, and the atmospheric pressure was about 90 Earth atmospheres. Although the arrival of the American Mariner 5 a day later in time helped to find the correct meanings of Soviet data, the Mariner itself gave some readings whose estimates were farther off from what is the best information today. Mariner data suggested 72 to 87 percent carbon dioxide, little oxygen, and the balance being either neon or nitrogen. The surface temperature was estimated as 371° C. Mariner 5 also detected what might have been a slight magnetic field, but no radiation belt. The Russians revealed that an operating replica of Venera 4 was kept in an environmental chamber on Earth through the entire period of the flight to duplicate as nearly as possible the same circumstances so as to serve as a systems check and to give early warning of problems in order that they might be solved on Earth in timely fashion and new commands sent to the actual flight. The flight was monitored in 114 communications sessions during the several months of the voyage. Power was supplied as in the other Zond flights partly from solar cell panels, tilting them away from maximum direct exposure to the Sun as the flight moved closer to that body. Chemical batteries served as buffers. Special attention was given to communications because of the sad results on earlier flights often related to communications difficulties. As the bus approached the planet, a command was sent to orient the main antenna toward Earth and signal strength at Earth jumped 300-fold. Doppler changes in signals provided data on its speed and stability. Once the final approach began, the ship was switched to its autonomous program. After separation of the capsule and opening of the parachute, the capsule's own directional antenna was deployed so that signals were still 20 percent the strength of those of the main parabolic antenna of the bus.

The initial departure from the Earth orbiting platform would have made Venera 4 miss the planet by 60,000 kilometers, so a midcourse correction was applied July 29, to aim it for the visible center of the planet. During its entry, it is believed the capsule withstood temperatures in the range of 10,000 to 11,000° C. The capsule had been

designed to withstand pressures up to 100 atmospheres and loads up to 300 G (compared with the 10 to 12 G a man can withstand for the same length of time).

Just five days after the launch of Venera 4, Kosmos 167 was sent to Earth orbit, and from its timing and behavior, it was intended to be the second Venera of the 1967 window, but the Zond rocket failed to fire, leaving it stranded in Earth orbit.

9. 1969 Venus Attempts

On January 5, 1969, Venera 5 was launched toward Venus using the same A–2–e launch vehicle as its predecessors. The payload weighed 1,130 kilograms. From the outset it was identified as intended to gather additional atmospheric data. The probe carried not only the usual metal pentagon with the Soviet coat of arms, but a bas-relief of Lenin's head. The Zond rocket, escape stage "e", was fired from its orbiting platform over Africa. Most details of the flight were as already described for Venera 4. This bus jettisoned its capsule to hit the atmosphere at a speed of 11.17 kilometers per second, which was reduced aerodynamically to 210 meters per second when the parachute was opened. For 53 minutes while suspended from the parachute, data were returned about the atmosphere. Further details are discussed in connection with the following flight.

Venera 6 was launched five days after Venera 5, January 10, 1969. It was a close duplicate of its immediate predecessor, of identical weight, and carrying the same symbols and instrumentation. It, too, was slated to land on the night side of Venus, as were Venera 3, 4, and 5. Venera 6 reached Venus on May 17, a day after Venera 5. The hope in running two flights so close to the same pattern was to improve the cross calibration of results for consistency in data readings.

During the course of the flights, some 1,500 commands were sent to the two stations in 136 communications sessions (73 to Venera 5 and 63 to Venera 6). Semidirectional antennas were used in the first two months of the voyages, and then the parabolic antennas of 2 meters diameter were aligned whenever high capacity data links were needed. Considerable information was stored in tape recorders on board, which could be emptied during a communications session, ready for refill with fresh data.

As with Venera 5, Venera 6 deployed its parachute after slowing down aerodynamically, and data were returned for 51 minutes.

The Russians supplied further information on orientation of the bus. When it was time to use the high gain directional antenna, the Sun seeker searched for the Sun, and then using the Sun direction as an axis, the ship was rotated until the Earth tube found Earth at which point it locked on and the antenna was correctly pointed.

These two Venus probes were also matched by a replica in an environmental chamber on Earth for diagnostic purposes. The claim was these latest Zonds were built to a higher standard of resistance to heat and pressure than Venera 4. The resistance of the ships to G load was raised to 450 as opposed to 300 of the earlier model. Instruments in the probe bus were supposed to function between 0 and 40 degrees Celsius, but in actual fact were held between 10 and 25 degrees. Because of the more rugged construction and better protection, the parachute size was cut to one third that of Venera 4 to permit a more rapid

descent through the atmosphere to enhance the chance of survival closer to the surface.

While discussing these craft, the Soviet Chief Designer predicted that future automated craft would fly to Mars, dig samples, and return these to Earth.

In March 1970, the scientific findings of Venera 5 and 6 were released for comparison with Venera 4 with these results:

TABLE 2-1.—ATMOSPHERE OF VENUS, EARLY SOVIET DATA

Atmospheric components	Venera 4 final data	Venera 5 and 6
CO_2 (percent)	90±10	97±4
N_2 (percent)	≤7 (possibly ≤2.5)	≤2
O_2 (percent)	0.4–1.5	≤0.1
H_2O (at P 0.6 atm) mg/liter	1–8	~11

SOURCE: Vinogradov, Acad. A.P., et al.: Study of the composition of the Venerian atmosphere on Venera 5 and Venera 6 automatic stations. Doklady Akademii Nauk SSSR, Vol. 180 No. 3, pp. 552–554.

It will be observed that the two sets of results bear a relation, but that the later readings brought some noticeable shifts in the conclusions. Especially, the Soviet position had shifted from an estimate of surface pressure from 22 atmospheres to 100 atmospheres, and the temperature from 280° C. to 500° C.

10. *1970 Venus Attempts*

Venera 7 was launched on August 17, 1970 with an A–2–e launch vehicle and weighed 1,180 kilograms, the heaviest yet of the Zond payloads sent to the planets. It followed the familiar pattern of placement in Earth parking orbit with the use of a Tyazheliy Sputnik. From this platform the Zond rocket was fired toward the end of the first revolution to send it toward Venus. The mission was described as designed to conduct further studies of the atmosphere of Venus, as well as other studies of the planet.

On December 12, 1970, as Venera 7 approached Venus, the solar cells of the main bus were used to charge the batteries of the landing capsule, and the temperature of the capsule was lowered to minus 8 degrees Celsius. On December 15, only 14 seconds later than estimated, Venera 7 entered the atmosphere of Venus at 7:58:44 Moscow time. This signal reached the Soviet Union at 8:02:06. The speed was close to 11,600 meters per second, about as estimated. As soon as the atmosphere affected the stability of the vehicle so that it lost its lock, this automatically triggered the separation of the landing capsule. After aerodynamical braking slowed the capsule to 250 meters per second, the parachute system was deployed, and the antenna was extended. Its signals to Earth continued for 35 minutes. In light of the limitations with its predecessors, this capsule had been made still heavier and shaped as a perfect sphere for greater strength, and with no holes drilled through its shell which might prove weak points during entry. Instead, only after the top hatch blew off to deploy the parachute and antenna were the sensors exposed.

With no more news at the time from Soviet sources, Western observers concluded once again that the environment of Venus had been too much for the capsule. But apparently after the 35 minutes of strong signals ended, the Russians continued to tune in the hiss of electronic

"noise" from space, and to apply advanced computer techniques to their recordings. On January 26, 1971, they announced that these studies had found buried within the noise an additional 23 minutes of coded telemetry from the capsule with only about 1 percent the signal strength of the earlier signals, which at best took sensitive equipment to receive. We do not know whether the craft tipped to misalign the antenna or some other local environmental factor cut signal strength. But for the first time, a man-made object landed on another planet and returned data to Earth. The surface temperature was found to be 475 degrees Celsius, plus or minus 20 degrees. The pressure was found to be the equivalent of 90 times that of Earth surface atmosphere, plus or minus 15 atmospheres. These data were a good fit with the extrapolations of both earlier Soviet and U.S. estimates. As the capsule descended through the atmosphere, the temperatures and pressures rose as expected. On the surface, the data remained virtually constant which served as an important indication the surface had been reached. Doppler shifts in signals on the way down also measured the rate of drop of speed which disappeared in the data at the surface. It is likely that after 23 minutes, the intense heat of the surface finally penetrated the vitals of the capsule to disable it ending further transmission.

Just five days after the launch of Venera 7, Kosmos 359 was placed in a low Earth orbit at the correct time for a Venus launch. From the Tyazheliy Sputnik, a payload was separated, and fired into a slightly more eliptical orbit, but evidently the Zond rocket cut off before building up much speed after its ignition. It decayed after 76 days.

11. 1972 Venus Attempts

Venera 8 was launched on March 27, 1972 using the A–2–e launch vehicle and orbital launch platform technique to send the Zond rocket on its course toward Venus. This payload also weighed 1,180 kilograms like its immediate predecessor. It also carried pennants with the Soviet coat of arms and the bas-relief of the bust of Lenin. Further details were that the escape rocket burn was for 243 seconds and that signals were being received on 928.4 MHz.

In contrast to all the previous night-side landing attempts at Venus, this capsule was separated to land on the day side, obviously near the rim of the visible disk of the planet since Venus was both near Earth, relatively speaking, in its orbital path, and closer to the Sun than Earth. There had been a course correction on April 16, and 86 communications sessions during the flight. The capsule was separated at 1040 Moscow time on July 22, 1972. Speed was cut from 11.6 kilometers per second to 250 meters per second. The payload measured brightness, temperature, atmospheric pressure, and something of the nature of surface soil. The landing came at 1229 Moscow time. This time signals continued for 50 minutes from the surface. It found the temperature on the day side very much like night temperatures, but the hour at the launch site was early morning, which may not be totally representative. While the weight of the capsule was the same as on the previous flight, with surer knowledge of the environment, some strength was traded off for more instrumentation. This time the temperature was found to be 465° C. and the pressure 93 Earth atmospheres. Brightness equalled that on Earth just before sunrise. This time

a dual antenna system was used on the capsule. In addition to one directly on the capsule, a second tossed to one side on landing was also used. The first 13.3 minutes of data came from the main antenna, and the next 20 minutes from the secondary antenna, and then the remaining 30 minutes came from the main antenna again.

Analysis of the soil of Venus, a new feature, was incomplete, but suggested a soil density of 1.5 grams per cubic centimeter. The soil showed 4 percent potassium, 0.0002 percent uranium, and 0.00065 percent thorium. This suggested rock similar to granite.

On March 31, Kosmos 482 was launched at the right time to be a Venera flight. Again, there was payload separation from the orbital launch platform, but an early cutoff which left the Zond rocket and payload in an eccentric orbit with the apogee sufficiently high that the payload remains in orbit now more than three years later.

F. THE SECOND GENERATION LUNAR PROGRAM

1. Change of Technology

Luna 1, 2, and 3 had made direct ascents from Tyuratam to fly toward the Moon with net payload and total weights on the escape trajectories as follows: 361.3 and 1,472 kilograms; 390.2 and 1,511 kilograms; 278.5 (in A.I.S.) and 156.5 (in carrier rocket) for a combined weight of 435 and 1,533 kilograms respectively. All three flights had used the A–1 vehicle; that is, the standard original ICBM, plus an upper stage which tripled the lift capacity over that of the A vehicle alone as used for the first Sputniks.

But the planetary program starting in 1960 had introduced an entirely new and more powerful upper stage, which replaced the original lunar upper stage. This planetary upper stage made it possible to raise the demonstrated weight in Earth orbit from about 4,700 kilograms to about 6,500 kilograms, and later even to 7,500 kilograms. This also afforded an opportunity to mount a more ambitious lunar exploration program, by placing a Tyazheliy Sputnik orbital launch platform in orbit, as well as the separated third stage rocket casing. From the platform, generally over Africa, while completing the first revolution around the Earth, a probe rocket fourth stage could be fired to send a Zond away from Earth, carrying an A.I.S. On this basis, the weight of the gross payload could rise to 1,400 kilograms and better, not counting the added weight of the separated probe rocket which might be another 440 or even 1,000 or more kilograms.

2. 1963 Moon Attempt

The first improved lunar rocket was launched on January 4, 1963. It failed to leave Earth orbit. Because it came during the period the Russians were uncertain as to how to describe such failures when failures were not acknowledged, this flight went unannounced until the United States disclosed it later in the spring in connection with the five Soviet planetary failures also stranded in Earth orbit in 1962.[8]

Luna 4 was launched successfully on April 2, 1963 and because it followed its planned trajectory, it was acknowledged and named by the Russians. It weighed 1,422 kilograms. Unfortunately, as it ap-

[8] Letter of June 6, 1963 from Ambassador Adlai E. Stevenson to the Secretary General of the United Nations.

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proached the Moon, it became evident the path was not quite correct, and it missed the Moon by 8,500 kilometers, entering a barycentric orbit around the Earth. Because its radios fell silent and these orbits are especially difficult to calculate through many completions, it is not certain whether it is still in this orbit or whether on some pass as it re-approached the Moon it was accelerated to be flung off into heliocentric orbit.

3. 1965 Lunar Attempts

A lunar attempt occurred on March 12, 1965, and failed to leave Earth orbit. With Russian public information rules settled on calling such failures Kosmos, this was named Kosmos 60 and passed off as routine.

Luna 5 was launched on May 12, and when its retrorocket system failed, it impacted in the lunar Sea of Clouds.

Luna 6 was launched on June 8. Because a midcourse correction failed, it missed the Moon by 160,000 kilometers. Although it may have gone into barycentric orbit, it is thought more likely to have gone to heliocentric orbit.

Luna 7 was launched on October 4, and the flight went well until the last minutes. Too early a retrofire and cutoff permitted it to impact in the lunar Sea of Storms too harshly to survive.

Luna 8 was launched on December 3, and again the flight went well until the closing minutes. Retrofire was late, and velocity was too high for survival when it impacted the lunar Sea of Storms.

Through all of these flights the exact mission had not been described, but it seems fairly evident that after the early strike missions and photo-fly-by, the missions from 1963 through 1965 were all aimed at a survivable landing for instruments on the lunar surface. This obvious supposition was later officially confirmed by the Russians after they attained successes.[9]

It is rather interesting to compare the problems experienced by the Soviet Union and the United States in their respective unmanned lunar landing programs. The time target for both was to achieve such missions in 1963. In the United States, its Surveyor craft actually was not ready for launch until 1966, when it became an outstanding success. The Soviet Union began making actual landing attempts in 1963, but did not meet success until 1966. This mission was more limited in its accomplishments than the Surveyor mission, but it did come first by a narrow margin, and answered the most basic questions about the problems of landing and what the surface was like.

4. The 1966 Lunar Attempts

Luna 9 was launched on January 31, 1966, and a day later was announced as a soft landing attempt. Launched at Tyuratam by an A-2-e vehicle, it used the orbital platform technique to send its Zond probe toward the Moon. The payload at this stage weighed 1,583 kilograms, and consisted of three basic parts: The automatic lunar station itself which was to make the survivable landing on the Moon; motor units for making midcourse corrections in trajectory and for braking on approach to the Moon; and compartments containing apparatus to control the flight. That control equipment not needed during the brak-

[9] TASS, April 4, 1966, 0756 GMT.

ing maneuver or thereafter was contained in two underslung containers which were to be detached independently when the braking rocket was turned on.

The automatic station was a hermetically sealed container with radio equipment, a program timing device, heat control systems, scientific apparatus, sources of power, and a television system. The device had a shock absorbing system to soften the blow of landing, and then opened four petals outward which had protected the television system. Extended, they tended to stabilize the craft on the surface. With the petals open, spring controlled antennas also flipped out into operating position, and the TV camera rotatable mirror system could begin a panoramic survey of the surroundings, both by revolving and by tilting.

The propulsion unit consisted of a rocket chamber with pumping system for the propellants, flight stabilization controls, and fuel tanks.

The control compartments contained a complex of gyroscopic and control instruments, electronic-optical devices for orientation of the station in flight, a system for radio control in orbit, a program timing device, a radio system for the soft landing, power sources, and micromotors for orientation purposes.

The spacecraft made its landing in the Ocean of Storms, with Pulkovo Observatory at Leningrad catching this on film at 21:45:30 hours, Moscow time, February 3, 1966, to become the world's first survivable landing on that body. This location is at 7°8′ N. and 64°22′ W. The approach to the Moon had been preceded by midcourse corrections, and data were supplied to the craft as to the amount of braking impulse required to achieve the landing. Telemetry return to Earth confirmed the conditions of the craft and that the right commands had been received. Final orientation occurred one hour before touchdown. At an altitude of about 8,300 kilometers, the craft assumed a strictly vertical position in relation to the Moon, and was held in this position by its sensors. At 75 kilometers, 45 seconds before touchdown, the retrorocket was switched on. Just before this the two compartments no longer needed in the operation were jettisoned to save weight. At the moment of touchdown, the station with its shock absorber was separated from the motor unit to land nearby. It took 4 minutes 10 seconds to deploy the equipment and begin radio transmissions. It was about seven hours before television transmission began.

The Russians did not immediately release the pictures from the Moon, but Jodrell Bank in England was following events, and by hooking up a press wire facsimile machine the British were able to make public the first views from Luna 9. The British picture, lacking calibration data, distorted the scale in one dimension, and the combination of this distortion plus the unauthorized release annoyed the Russians according to TASS. But the British release created a credibility for the project which might otherwise have been harder to establish in some quarters where Soviet reports tend to be discounted.

Batteries ran down in the craft on February 6 after seven radio sessions of 8 hours 5 minutes total duration, and the three series of television pictures when assembled provided a panoramic view as planned. The total weight of the landed small station was 100 kilograms. The camera itself weighed only 1.5 kilograms. A non-direc-

tional antenna was used to return the signals to Earth. The pictures showed rocks close at hand and the horizon at a distance of 1.5 kilometers away. Pictures were taken twice on February 4, and once on the 5th, so that with changes in shadow length, different objects were highlighted. Also, there was some shift in the payload between the second and third picture series giving a slightly different perspective. As near as can be judged from the Soviet accounts, each picture series involved in the panoramas included nine positions of the mirror.

Kosmos 111 was launched on March 1, 1966, but failed to leave its low Earth orbit from which it decayed in two days. It is generally assumed that it was intended to be a lunar orbiter mission, but it could have been another lander.

On March 31, 1966, Luna 10 was launched toward the Moon from an orbital launch platform. The weight of payload sent toward the Moon was 1,600 kilograms. Apparently, the vehicle was structured like Luna 9 in terms of its propulsion, guidance, orientation, and communications elements, except that the landing station was replaced by an orbital station of a different nature. Luna 10 was braked to enter lunar orbit, the first man-made object to achieve this. The main propulsion unit was separated from the payload after lunar orbit was attained, and the remaining payload weighed 245 kilograms. The initial orbit was about 1,017 by 350 kilometers with an inclination of 71°54′ to the lunar equator and had a period of 178.25 minutes. Although the prime purpose of the flight was science, at the 23rd Congress of the CPSU (Communist Party, Soviet Union) the delegates were brought to their feet when the payload circling the Moon played back to Earth the strains of the Internationale.

Luna 10 was not equipped with a television camera, but it had a variety of instruments to return data. One task was the reporting of meteoritic impacts on the payload. Another was to determine the thermal characteristics of the Moon without interference of the Earth's atmosphere. Another had to do with study of the Moon's magnetism, if any. Also, there was a need to establish some notion of the irregularities of the Moon's gravitational field.

One midcourse correction had been required on April 1, and then when it was 8,000 kilometers from the Moon, the braking engine was fired to drop the speed from 2.1 kilometers per second to 1.25 kilometers per second so that it could go into orbit. The payload was separated 20 minutes after the end of retrofire.

The listed instruments were: A meteorite particles recorder; a gamma spectrometer; a magnetometer; instruments for studying solar plasma; a recorder for infrared emissions from the Moon; and devices to measure radiation conditions in the Moon's environment. The gravitational studies were pursued as a byproduct of the tracking. The device was battery-powered, but by careful husbanding of this electrical supply, it was possible to continue to receive radio signals from the payload until May 30, 1966. By this time, there had been 460 orbits of the Moon, and 219 active transmissions of data.

By placing the payload in an orbit inclined at 72 degrees to the lunar equator, it was able to take readings over much of the surface over a period of time. The stunt of sending back music was achieved by programing some semiconductors to emit a definite sequence of electrical oscillations.

The payload found a magnetic field around the Moon about 0.001 the strength of that around Earth. Cosmic ray background levels were slightly high, as expected. The natural radiation of lunar rocks was determined to resemble most closely that of basalt on Earth. The intensity of meteoritic impacts was higher than in interplanetary space. Some of the observed radiation from the lunar surface was believed to come from interactions with cosmic rays rather than from natural radioactivity within the rocks. Particles of the Moon's radiation belts were estimated to be present to only one-one hundred thousandths that of Earth in the corresponding zone. The gamma ray spectrometer was that of the multiscintillation type, to cover energies between 0.3 and 3 million electron volts. The magnetometer had three channels at reciprocally right angles. The ion trap was modulated to register positive ions down to an energy level below 10 electron volts, while the four electron traps would measure a full stream of ions if exceeding 50 electron volts.

Luna 11 was launched on August 24, 1966 with a weight sent toward the Moon of 1,640 kilograms. It was launched from an orbital launch platform, and later a midcourse correction was performed. It approached the Moon on August 28, when retrorockets were fired to place it in lunar orbit. Less was said about this flight than about Luna 10. Most of the early bulletins merely reported that communications were stable, and how many orbits had been accomplished. A month after launch, the mission was described as studying gamma and X-ray emissions of the Moon to determine more exactly the chemical composition of the Moon, and studying gravitational anomalies in the Moon. Additionally, this satellite was studying the concentration of meteoritic streams, and intensity of hard corpuscular radiation near the Moon. This payload was put into an orbit between 1,200 and 160 kilometers, at an inclination of 27 degrees with a period of 178 minutes. Not much more was said until the announcement that the batteries had been used up by October 1, 1966, after 137 radio sessions, and 277 orbits of the Moon.

No picture has ever been released of this payload, and very little has been published about the findings. An early Soviet announcement suggested in a vague way that this was improved over Luna 10. Jodrell Bank intercepted signals that suggested that Luna 11 was intended to return television pictures from lunar orbit.[10] This combination of facts suggested that Luna 11 resembled Luna 12, the next in the series, but that it fell well short of its planned functions.

Luna 12 was launched on October 22, 1966 toward the Moon, also employing the usual orbital platform technique. A midcourse correction was carried out, and the ship was placed in lunar orbit on October 25. The orbit was first given as 1,740 by 100 kilometers with an "equatorial" inclination and a period of 205 minutes. Later it was announced as 1,200 by 133 kilometers, at an inclination of 10 degrees. On October 29, it returned pictures of the lunar surface by radio facsimile. The system used was to take pictures with a camera, develop these photographic films on board, and then scan the pictures for radio transmission to Earth. No weight was announced for this payload, but it was probably close to that announced for Luna 11.

[10] Reuters, Moscow, August 30, 1966, carried in the New York Times of August 31, 1966.

The appearance of Luna 12 differed from Luna 10 mostly because of the large radiator covering much of the instrument compartment. Those parts of the scientific apparatus which did not need to be air tight—the antennas, and the gas reserve spheres for the microsteering engines were also external to the body of the station. The propulsion unit of the liquid fuel rocket, its pumping system, control devices, and fuel tanks were little changed from earlier Luna or Zond payloads. Again, there were separate attached compartments to contain the astro-orientation devices consisting of gyroscopes, electro-optical instruments, and program timers to be cast loose just before retrofire. These were both to orient the total craft for midcourse and braking maneuvers, and those that went with the payload to align the spacecraft during picture-taking sequences while circling the Moon. The main instrument compartment of the orbiter contained the major experiments, radio receivers and transmitters, and the automated photographic and facsimile picture processing equipment. Pictures apparently were first transmitted to Earth at a fast data rate for a quick scan at the deep space tracking facility, and then retransmitted at a slower rate to maximize the detail for more thorough study later. The pictures contained 1,100 lines of scan, to give a maximum resolution of 15 to 20 meters. When the last had been transmitted, the facsimile/television unit was switched off to conserve power. It is not known how many pictures were taken, compared with Zond 3 which had taken 25. Only two or three seem to have been made public from the Luna 12 flight. Radio transmissions from this craft ended on January 19, 1967, after 602 orbits of the Moon, and 302 radio sessions with Earth.

Luna 13 was launched on December 21, 1966. It repeated the operational steps of its predecessors, and landed on the Moon on December 24 in the Sea of Storms at 18° 52′ N. and 62° 0.3′ W. Four minutes after landing it began to transmit to Earth, having opened its petals, sprung out antennas, and warmed up radios. A day after landing, it began to send back photographs of the surface in the same manner as Luna 9. The first successful lander had gone into mountainous terrain (lurain), and this one was on a lunar seabed, but the general appearance of the surroundings were much the same. Luna 13 differed from Luna 9 in that it carried two telescoping arms which were gunpowder-controlled, once extended, to swing outward and down from the craft to thump the lunar surface so that sensors could judge something of the density and firmness. The 16 degree tilt of the station away from horizontal meant that the panoramic swing of the mirror on the camera permitted views at a distance of less than one meter to show objects of millimeter size, graduating out to other views of the lunar horizon.

Some days after the landing, the lunar soil properties were described as having to a depth of 20 to 30 centimeters the mechanical properties of average density terrestrial ground, but general density at the landing site was believed to be less than typical Earth ground density. Little radioactivity in the soil was detected. The impact device could develop a pressure of 23.3 kilograms to force a rod into the soil. These data from the impact device were compared with accelerometer data from the actual deceleration in landing, leading to reasonably consistent findings on the mechanical properties of the soil. The actual density was estimated by direct measurements of the volumetric weight

by means of gamma quanta. Density was estimated as not exceeding one gram per cubic centimeter, much less than both terrestrial ground or average density of the Moon.

It was also determined that the lunar surface reflects about 25 percent of particles of space radiation which fall upon it, consistent with the Luna 9 data. Observed stones looked like local debris, not meteorites.

It was also revealed that the camera and television system required about 100 minutes to transmit an entire panoramic view of the surroundings. From the absence of further reports, it is likely the batteries ran down before the end of December 1966.

5. 1968 Lunar Attempt

Sixteen months were to pass before the concluding flight of the second generation Luna series came about. Luna 14 was launched on April 7, 1968. After the usual midcourse correction, the braking system slowed it on April 10 to place the payload in a lunar orbit, ranging from 870 to 160 kilometers, at an inclination of 42 degrees, and with a period of 160 minutes. No weight figures and no pictures were released on the craft. But the listed experiments most closely resembled those of Luna 10, the first orbiter. These were aimed at studies of interactions between the mass of the Earth and the Moon, studies of the Moon's gravitational field, the propagation and stability of radio communications between Earth and spacecraft, measures of the stream of charged particles from the Sun, and formulation of a precise theory for the Moon's movement. Not announced until two years later, this vehicle and Luna 12 earlier had carried out tests of the type of electric motor used to provide locomotion on Lunokhod 1 in 1970.

The President of the Soviet Academy of Sciences, Keldysh, stated that the flight would have enormous significance for future, more ambitious flights to the Moon. No published data have been discovered to indicate the termination of this experiment, although it was still operating normally at the end of April 1968.

G. THE FIRST MANEUVERABLE SATELLITES

On November 1, 1963, Polet 1 was placed in Earth orbit. Khrushchev himself pointed to the designation of it as being the first of a series, saying that a whole new era was opening for craft able to maneuver after attaining orbit. The flight entered an initial orbit with an apogee of 592 kilometers and a perigee of 339 kilometers. It was announced to have made many maneuvers of a lateral nature and of altitude, so that the final orbit was 1,437 by 343 kilometers, and the inclination was 58° 55′. Little more was said of the specifics of the flight, although there were many comments on the importance of being able to maneuver.

On April 12, 1964, Polet 2 was also placed in Earth orbit. Again, the Russians stressed its ability to maneuver repeatedly, but they did not publish the details on these maneuvers. The final orbit was described as 500 by 310 kilometers, at an inclination of 58.06 degrees.

As discussed earlier in this report, we can describe the launch vehicle used as an A–m combination. Strangely, the program was never again identified, and one may speculate that it served its purpose, that the technology was incorporated into some other classes of vehicles as a subsystem.

H. THE ELEKTRON PROGRAM

On January 30, 1964, the Soviet Union made its first launch of two payloads with a single launch vehicle, subsequently identified by them as having been put up by their standard vehicle (A–1). Elektron 1, weighing 330 kilograms, was put into an eccentric orbit of 7,100 by 406 kilometers at an inclination of 61 degrees and a period of 169 minutes. Elektron 2, weighing 445 kilograms, was put into an even more extreme orbit of 68,200 by 460 kilometers, also at an inclination of 61 degrees, and with a period of 1,360 minutes. Both were fairly complex spacecraft. Elektron 1 was cylindrical with six solar panels which folded out away from the craft, and it carried multiple antennas at both ends. Elektron 2 was shaped like the cupola of a building, was mostly covered with solar cells, had antennas at both ends, and a magnetometer boom at its pointed tip.

The purpose of these flights was to map the radiation belts and to supply synoptic readings. Western observers suggested that in light of their probable power supplies which should be available from such large expanses of solar cells, and the announced experiments on board, these craft could easily have the power and weight to carry additional unannounced experiments. For example, they could easily have carried nuclear explosion detection instruments, like those of the U.S. Vela series, although the latter fly in circular orbits at about 100,000 kilometers circular orbit above the Earth.

On July 10, 1964, Elektron 3 and Elektron 4 were put up into similar orbits in another dual launch. Elektron 3's orbit was 7,040 by 405 kilometers, 60.86 degrees inclination, and a period of 168 minutes. Elektron 4 was in an orbit of 66,235 by 459 kilometers, inclination of 60.86 degrees, and period of 1,314 minutes. These flights, about six months after the earlier series, and launched about 12 hours later during the day provided a second set of readings for comparison with the first flights. Weights were not announced, but presumably were a close repeat of the earlier flights. There have been no more since that time.

I. THE PROTON PROGRAM

It was appropriate that after the eccentric orbit, relatively small Elektron flights, that the largest of Soviet scientific flights should be called Protons. An earlier chapter of this report has already described the Proton or D class launch vehicle, about three times the capacity of the standard A class launch vehicles. As noted, to this day, no complete photograph of this launch vehicle has been made available.

1. Proton 1

On July 16, 1965, the U.S.S.R. announced the launch of Proton 1, said to weigh 12.2 metric tons, into an orbit 627 by 190 kilometers at an inclination of 63.5 degrees, and with a period of 92.5 minutes. The rocket was described as having a power output in excess of 60 million horsepower. The payload was described as a massive cosmic ray measuring experiment, to gather evidence on cosmic ray primaries up to an energy level of 100 trillion electron volts (10^{14}eV). Later, when a replica of the payload was put on display, it was found to consist of a short cylinder about 4 meters in diameter, with four large solar cell panels or paddles which folded out from it, and a number of antennas.

Cradled within the cylinder was the experiment package as if within an annulus. Separate cutaways of the experiment showed typical blocks of metal, paraffin, and plastic as often used for cosmic ray experiments. The ship was able to transmit many channels of telemetry. The low orbit led to its decay after 87 days.

2. Proton 2

This similar payload was launched on November 2, 1965, and lasted 92 days. It was in an orbit of 637 by 191 kilometers, at an inclination of 63.5 degrees, and with a period of 92.6 minutes. It also was announced as weighing 12.2 metric tons. Western optical studies of the accompanying debris in Earth orbit left in doubt whether the whole core vehicle was in orbit with the payload (the D version) or an upper stage (the D–1 version).

3. Proton 3

After eight more months, Proton 3 was announced as launched on July 6, 1966. It was in an orbit of 630 by 190 kilometers, at 63.5 degrees inclination, and with a period of 92.5 minutes. It also had an announced weight of 12.2 metric tons. Decay came after 72 days. This flight continued the study of cosmic rays, including solar cosmic rays, and their energy spectrum and chemical composition in the range up to 100 trillion electron volts. It measured the absolute intensity and energy spectrum of those of galactic origin, and it sought primary cosmic rays for any particles which might have a fractional electrical charge. Specific reference was made to searching for the postulated fundamental particle, the quark. In any case, the orbital station afforded study opportunities impossible to pursue on the surface of the Earth.

Considering that three such similar payloads were flown, and probably without too efficient a use of the new launch vehicle, it seemed perhaps the primary purpose of the flights was to test the new vehicle with science getting a free ride, much like the three early flights of Saturn I which carried repetitive Pegasus meteoroid experiments.

4. Proton 4

The final Proton flight came on November 14, 1968, as an improvement over the predecessors. It was put into an orbit of 495 by 255 kilometers at an inclination of 51.5 degrees, the inclination used hereafter for D-vehicle launches, with a period of 91.75 minutes. It decayed after 250 days. This time the payload weight was listed as 17 metric tons.

Later, a replica was put on display, and it was substantially like its predecessors, but at one end there was a blunt, conical nosecone, even though the payload was non-recoverable. It had a number of rod antennas, and the same kind of solar panels. This time there was agreement among Western optical observers that the accompanying spent rocket casing in orbit was on the order of 12 meters long, 4 meters in diameter, the same as seen with the Luna 15 and Zond 4 flights (the D–1 version).

The Soviet description of the experiments this time raised its capacity to measuring cosmic ray energies up to a level of one quadrillion electron volts, (10^{15}eV) and to do chemical analysis studies in the range between 10 and 100 trillion electron volts. It was also to study

the possible collisions of cosmic ray particles with the nuclei of hydrogen, carbon, and iron in the range of 1 to 10 trillion electron volts, and to study the dynamics of collisions of cosmic ray particles in the 10 to 100 trillion electron volt range with the nuclei of atoms. They continued their search for primary particles with fractional electric charges, and to measure the intensity and energy spectrum of high energy electrons. They still hoped to find quarks. A number of the instruments had been refined over what were used in the earlier flights.

The main instrument used on the Proton station was an ionization calorimeter. It consisted of a considerable number of steel bars between which were special plastic scintillators. When a cosmic ray primary would strike an iron nucleus, secondary particles spread out to collide with still other nuclei through many generations. A lump of carbon serving as one half and a lump of polyethylene as the other half of the instrument were used as measuring devices where the interactions of particles could be studied.

II. The Kosmos Program

A. THE NEED FOR KOSMOS

In the first five years of the Soviet space program, only 15 flights were successful in attaining orbit. All had come from Tyuratam, and all had used the large standard vehicle in its several forms, the A, A–1, A–2, and A–2–e. It is possible that only one or two launch pads were in use. In a sense, despite the very considerable achievements of the program, it represented a current operation on a shoe string, exploiting to the utmost the investment which had been made. Lead times suggest that by the time the first Sputnik flew, work undoubtedly was already well along in planning use of the upper stage which permitted the first Luna flights, and perhaps the Vostok manned ship was also under actual development.

But the time had come as these early flights occurred to flesh out the Soviet space systems beyond proof of principle into both practical applications flights and more ambitious exploratory missions. One obvious need was to bring into operation a simpler launch vehicle which would be more economical for modest missions, in the same way that NASA uses not only its complex orbiting space observatories but also its simpler Explorer payloads. Secondly, the Soviet Union needed to be able to fire its launch rockets at additional inclinations, from places where these changes of azimuth would not risk dropping first stages on populated regions. Third, if the pace of such flights was to pick up, it would be useful to spread the launch range workload more widely.

The Soviet Union was in the slightly contradictory position of describing all of its space activity as devoted exclusively to scientific purposes, codefined as peaceful in nature, and probably also self-defined to include all technological endeavors as automatically scientific. But at the same time they were exploiting to the utmost the concept of operational and strategic surprise, to keep their American rival off balance and their world image one of successful leadership. Startling predictions were made as to what they planned to do, but without a specific time table, and enough of these missions were

accomplished to create that sought image of purposeful success. Information on failures was kept carefully hidden for many years, and constantly the theme was pressed that these sure successes were the direct result of the superiority of the socialist system. It was flatly stated repeatedly for the early years that there were no failures in the Soviet program. Secrecy was defended both on the score that the Soviet Union did not boast before it had accomplished deeds worth advertising, and that its use of powerful military missiles as carrier rockets, the front line of defense against aggressive imperialism, needed protection against Western spying designed to help the United States catch up in a field where the Soviet technical lead was said to be strong.

At the same time that the U.S.S.R. was drawing comparisons unfavorable to the United States by contrasting Soviet spacecraft weighing tons and U.S. Vanguards like grapefruit, they were reading in the American press about U.S. plans for Pied Piper, Big Brother, Sentry, and other project names for further generations of U.S. military spacecraft in quite a different league from the first U.S. small scientific payloads. It would be hard to believe that Soviet technicians were any less aware than our own, that spaceflight provided new and interesting opportunities for applications of advanced technology. But how were such Soviet military applications to be made without undercutting their own propaganda contrasting their scientific and peaceful image with their claims that the U.S. Department of Defense was already militarizing space for purposes of world aggression?

There was a body of Soviet literature which looked beyond the temporary license of the IGY agreements permitting overflights of national territories to proposals that all military flights in space should be subject to international prohibition. Observation from space was called spying, and not only the lawyers were critical, for military figures spoke of the need to take countermeasures. Premier Khrushchev spoke scathingly of people who peek into others' bedrooms, promising that satellites would meet the same fate as the U–2 had on May 1, 1960. If the Russians were to protect their own freedom of action in space while not sacrificing the peaceful image they were carefully constructing, they needed an appropriate cover plan.

B. THE COVER PLAN OF KOSMOS

The United States proved sensitive and defensive about the Soviet charges that it was practicing aggression in space, and the trauma of the Gary Powers capture and subsequent collapse of public information policies had produced a very secretive attitude within some segments of the United States Government. This Government knew that gathering information was important to maintaining peace, and that this was not aggressive by our standards. No one knew what the Russians were up to within their closed and compartmented society. National security required that U.S. work proceed on several fronts against all the possible contingencies of rapid expansion of Soviet strategic missile capabilities, of Soviet bombs in orbit, of Soviet interception of U.S. payloads. Because the Soviet Union disclosed so little information which could be verified by normal means, it was vital that some notion of the order of battle and disposition of military resources

and hardware be known as a guide to the pacing of American protective developments. If there was a danger that our information gatherers were going to be "neutralized" by the Russians, then everything had to be done to protect the privacy of these U.S. national technical means, as well.

Some very carefully reasoned legal interpretations of the U–2 incident showed that such Government aircraft overflights in the air space of other nations were not necessarily espionage and illegal.[11] But the political reality of the U–2 and the storm it produced went far beyond abstract legal principles. By contrast, flight through outer space could hardly be considered invasion of air space. No logic would support the concept of sovereignty extending outward from Earth to sweep limitless regions of the universe as the Earth rotated on its axis. Nonetheless, in the absence of firm international law on such points in these early years, a cautious policy seemed appropriate.

Hence, in the fall of 1961, the United States information policy on its military space operations progressively tightened to withhold details of hardware and operations plans. By November 22, the first U.S. launch of unannounced purpose occurred. The occasional launches of this one category of flight drew such added attention from the world press that information policies had to be tightened even more, and extended to most military space flights. After the launch of Discoverer 38 in late February 1962, no more names were announced for flights with the same characteristics, and information disappeared on recovery of any capsules returned from space by the military. This contrasted with the news releases urged upon the press about such recoveries until that time. Later, even the previously widely publicized navigation satellites called Transit went under cover.

Thus it became United States policy from March 1962 on to have no public names for its military space flights, aside from some later exceptions where a variety of other agencies were sharing in the scientific and technological experiments to gather environmental data, to develop communications techniques, or to test some supporting systems such as gravity stabilization devices or tracking devices. Although the names and descriptions for the bulk of U.S. flights disappeared, the flights did not become truly secret. First of all, the fact of launch was announced locally at the launch site, naming the launch vehicle used. This was hardly a disclosure as private citizens in the areas adjacent to the launch centers could observe the obvious. Second, the orbital elements of most of these flights later were published in the NASA Goddard Satellite Situation Report. In more recent years, secrecy has extended to excluding from the Goddard report the orbital elements of some of these Defense satellites. Third, under international agreements, the names of all launch vehicles including the orbital elements even of the satellites no longer listed by elements with NASA are registered at the United Nations, not only for the payloads, but for all associated pieces of debris. Even with this record of name hiding but ultimate openness on where the satellites are in orbit, there followed some years of continuing Soviet criticism about these military operations. They even planted the suspicion in the world that

[11] Beresford, Spencer M. High altitude surveillance in international law. Paper given in Stockholm, Sweden, August 16, 1960 at the 11th Congress of the International Astronautical Federation.

U.S. flights had gone beyond passive military support to placement of weapons of mass destruction in orbit. This latter possibility can be analyzed to show its complete absurdity, but will not be done here. At the height of Soviet "hysteria" about U.S. overflights, even the low resolution pictures taken by the NASA TIROS weather satellites were described by some Soviet writers as "spy in the sky" flights.[12]

It has already been suggested that the Russians faced an information handling crisis of their own in the very months that the United States was "unwriting" its own history of articles about space observation, and was trying to defuse a potentially bad situation by toning down and taking the spotlight off U.S. military space flights and "provocative" program descriptions. Whether our policy was both correct and wise is a matter of opinion. In the long run it seems to have worked, but not necessarily for the reasons originally offered.

The Russians decided they wished freedom of action in a number of military space fields, and that their own withholding of information on coming programs could be protected with a very simple cover plan which gave as complete privacy as technology would permit while maintaining the wholly "peaceful" image of the first five years of spaceflight. This was simply to have a blanket, all-inclusive flight description which was generally correct or at least hardly challengeable which could be used for the bulk of their flights. At the same time 70 percent of all flights could be given the meaningless name Kosmos, and a serial number. This "openness' of name, immediate release of orbital elements, and peaceful Kosmos label, could be contrasted with the fact that half of U.S. flights were for the Department of Defense, had no name, no announced mission, and details on orbital path were withheld for weeks or months for belated release, sometimes after the flight was over. This Soviet practice was only a propaganda ploy, although an effective one, when in fact a cover name, serial number, and vague description provided no real information. The Soviet release of orbital parameters was useful, but presumably told no more than was already evident to the tracking systems of the United States and Britain.

Here is the text of the Kosmos announcement of March 16, 1962:

> A series of artificial Earth satellites will be launched from different cosmodromes of the Soviet Union during 1962. Another launching of an artificial Earth satellite was carried out in the Soviet Union on 16 March 1962. . . .
>
> The launching of the artifical Earth satellite continues the current program of studying the upper layers of the atmosphere and outer space in fulfillment of which a series of satellite launchings will be effected under this program from different cosmodromes of the Soviet Union in the course of 1962. The scientific program includes: The study of the concentration of charged particles in the ionosphere for investigating the propagation of radio waves; a study of corpuscular flows and low energy particles; study of the energy composition of the radiation belts of the Earth for the purpose of further evaluating the radiation dangers of prolonged space flights; study of the primary composition and intensity variation of cosmic rays; study of the magnetic field of the Earth; study of the short wave radiation of the Sun and other celestial bodies; study of the upper layers of the atmosphere; study of the effects of meteoric matter on construction elements of space vehicles; and study of the distribution and formation of cloud patterns in the Earth's atmosphere.
>
> Moreover, many elements of space vehicle construction will be checked and improved. The launching of sputniks of this series will be announced in separate reports. This program will give Soviet scientists new means for studying the physics of the upper atmospheric layers and outer space.[13]

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[12] Aleksandrov, Col. B. Spies in the cosmos. Red Star, Moscow, July 23, 1961, p. A.
[13] TASS, March 16, 1962, 1701 GMT.

Then when the second launch occurred on April 6, it was named Kosmos 2, and reference was made back to the press release for Kosmos 1. This same pattern has been continued through subsequent years and hundreds of Kosmos flights. The first three Kosmos flights clearly came from a new orbital launch site, the one at Kapustin Yar, and they flew at an inclination close to 49 degrees to the equator.

But Kosmos 4, announced with the same kind of a press release, was flown at the older inclination of 65 degrees, and after three days the TASS announcement read:

> The Soviet artificial Earth satellite Kosmos 4, launched on 26 April 1962, has been in orbit for more than three days and has flown in this period about 2 million kilometers. Throughout the world flight the systems and apparatuses on the satellite to carry out the exploration of cosmic space and the upper layers of the atmosphere worked well. In connection with the completion of the program of scientific research on 29 April, at a command from Earth, the successful landing of the satellite in a predetermined area of the territory of the Soviet Union was carried out. As a result of the launching of satellite Kosmos 4, valuable scientific data, which at present is being processed and studied, has been received.[14]

Thus was signaled that many separate programs, many different launch vehicles, and several cosmodromes would be used by the U.S.S.R., with individual purposes released only selectively, and in a minority of instances, under the general blanket cover label of Kosmos. Also, they were able to announce their successful recovery of a payload on land, without tying that work to a military program, which the United States managed to do when President Eisenhower displayed the first recovered Discoverer capsule after its ocean pick-up. The reference to using some flights to take cloud cover pictures was especially ironic, even humorous, after the earlier paroxysms the Soviet government went through when they put on display camera systems in Moscow, recovered from U.S. balloons launched to drift over the Soviet Union from West Germany, and intended for recovery in the area of Japan. The United States had described the purpose of the balloon flights to be that of gathering cloud pictures, but the Russians said they represented spying because of the resolution of the cameras.

C. BROAD CATEGORIES WITHIN KOSMOS

Especially with the advantage of hindsight, it is possible to sort out the Kosmos flights in almost all instances into broad categories. This process has been carried out in part through earlier sections of this report. The identification of launch sites and the distinguishing of different launch vehicles start this process. Beyond this, the public record of orbital elements is very revealing as repetitive patterns are studied, and these characteristics are compared with possible missions which would use such paths around the Earth.

As time passes, the Soviet scientific community publishes experimental results on those Kosmos flights which are scientific. This accounts for some of them, including use of A, B, and C classes of launch vehicles, even though the bulk of all three categories have no findings reported in either scientific journals or popular sources. When space applications flights for such functions as weather reporting, carrying human crews, and communications have appeared and ultimately been

[14] TASS, April 29, 1962, 1232 GMT.

described by TASS, it has been possible to find within the Kosmos label certain flights with the same characteristics of orbit or duration of flight. The manned flight precursors have been especially easy to spot not only for their orbital placement and recovery, but usually the radio frequencies used and sometimes even the broadcast of recorded human voices. For those Kosmos flights which ultimately are followed by scientific findings published, it is possible to note their special characteristics and identify follow-on flights of the same series even in advance of the ultimate publication of results.

Hence it is safe to say that Kosmos includes elements of programs devoted to science, to development of practical civil applications, and to testing precursors to manned ships to follow.

There are two further categories of Kosmos flights which cannot be identified as to purpose on the basis of later Soviet publications anything like as directly, and these flights make up the overwhelming bulk of all Kosmos flights. The smaller portion of the unknowns are flight failures, whose malfunctions are ignored by issuing a routine announcement of the flight which also says that incoming data are being received and studied. Examples of these are the deep space flights whose orbital platforms for some reason have not sent a payload on its way to the Moon or a planet. But the greater part of the Kosmos flights are ones that seem to have functioned and where despite the fact they number on the order of 500, no scientific finding has ever been published. These are almost surely military in character, and their probable missions will be discussed in another chapter.

D. TECHNIQUES FOR DEFINING KOSMOS MISSIONS

It has already been pointed out that the Soviet announcements alone when coupled with later publication of scientific findings and with later announced manned or applications flights permit positive identification of a substantial number of Kosmos missions, even though less than half the total. The nature of announced orbits even without elaboration provides a checklist of potential applications which would be consistent with the orbital location of the flights.

Beyond this, important indicators are supplied by the Goddard Satellite Situation Report which gives the orbital elements and then decay dates on not only the payloads but associated debris as well. Abandoned debris may reveal something about the staging and mode of operation or maneuver, if any, used by the flight. Rates of orbital decay over time may reveal something of the density or shape of the objects in orbit. If final decay from orbit occurs before natural decay by air drag would dictate, it is reasonably likely that retrofire was employed in a recovery attempt, or return to Earth was deliberately arranged to dump a large non-recoverable spacecraft in an ocean area. If pickaback payloads are separated later from the main payload, this fact generally can be noted in the public register. Clearly catastrophic events such as explosions in orbit are signaled by the large amount of debris, and the dispersion from the original single orbit tells something of the violence of the explosion. Payloads which were spin stabilized early in flight and then slowed down by unwinding "yo-yo" wires with weights are identifiable because these separated weights above and below the main payload are a standard tell-tale with such flights.

The Goddard report is inadequate by itself to answer all the questions that public sources of information could provide. The Royal Aircraft Establishment (RAE) at Farnborough in England gives a much more explicit description of all world flights, including Soviet, by labeling which objects are payloads, which are spent rocket casings, which are special capsules, and which are miscellaneous debris. The British also give the hour of launch which often helps to identify the launch site and sometimes the purpose of the mission. Because the RAE, too, is looking for repetitive patterns and they can add some data from optical or radar observations, they are able to list the shape, weight, and dimensions of most objects to the best of their estimating ability. They describe the orbit more completely than does Goddard by giving the date of orbit determination, sometimes with multiple entries, the estimated orbital life time, the semimajor axis, the orbital eccentricity, and the argument of perigee. This is in addition to the Goddard type information on apogee, perigee, inclination, and period.

Still more information on Kosmos flights is available from private observers whose findings may ultimately find their way to publication at least in summary form. The chief of these sources is provided from the team of observers linked with the Kettering Grammar School, Northants, England. Geoffrey E. Perry, the head science master of the school has led this effort with important support from his family, colleagues, and successive generations of pupils. Coordinated information comes from correspondent stations in Sollentuna and Malmö, Sweden, operated by Sven Grahn and Jan Ola Dahlberg, and one in Cyprus by Peter Wakelin. Horst Hewel in West Berlin and Richard S. Flagg in Gainesville at the University of Florida cooperate at times of manned space flight. Christopher D. Wood contributed data from Fiji until he returned to the United Kingdom.

The Perry effort first concentrated on the signal characteristics of the then mostly eight-day military recoverable photographic missions of the U.S.S.R. Doppler shift in signals made it possible to establish the flight path to a good degree of accuracy. When the flights were ready for recovery, the radio beacon was tracked, and the stages of retrofire, ionospheric blackout, parachute opening, touch down on the ground, and arrival of the pickup crew to turn off the final beacon could be logged with great precision.

Perry's studies proceeded to identify telemetry format so that even on the first revolution it has been possible to discern which flights fall into each of the several modes of operation, with most of the newer flights staying up 12 to 14 days. Often impending launches could be forecast because a spacecraft already in orbit would vacate its previous frequency, moving to a different one in order to free the original frequency for new launch coming within the day.

By study of the pen tracing of signals, Perry was able to correlate some of these readings with probable expenditure of photographic film during the flight, and to find some of the other housekeeping or environmental parameters being measured.

Hence, with the passage of time, these Kettering techniques have given a highly professional, consistently positive identification to many aspects of the Soviet space program from completely unclassified, private sources, which are not matched by any public release of data by the Soviet, United States, or British governments. The

general public interested in data on Soviet flights owes a debt to the Kettering Grammar School whose published findings in a few instances may have been factors toward influencing the official bureaucracies to ease up on the rigid suppression of what is essentially non-sensitive information about space flights. Perry has received recognition in many forms from both the scientific world and the lay world of government and press. His name appeared on the New Year's Honors List of January 1973, and he was personally invested with the order of MBE by Queen Elizabeth at Buckingham Palace on March 13, 1973. In January 1974, he was awarded the Jackson-Gwilt Medal and Gift of the Royal Astronomical Society.

E. KOSMOS SCIENTIFIC MISSIONS

As the foregoing discussion has suggested, the largest part of the Kosmos program is military. However, the program overall is so large that even the minority of flights which are scientific makes an impressively long list. By the techniques discussed above, it is usually possible to distinguish between scientific and military missions. The out and out military missions are discussed in detail in another chapter. The scientific missions can be tagged tentatively as they occur, based on external characteristics, and often it is a matter of waiting from a year to several years until the tentative assignment can be confirmed or reevaluated on the basis of published scientific findings. In addition to those flights with a primary scientific mission, there are a number of military flights which carry a separable scientific payload in pickaback form, and there are other scientific experiments which are incorporated as part of the main military payload. To the extent any of these categories can be identified or have been disclosed, they will be accounted for in the text to follow.

For convenience these missions will be treated by launch vehicle and by date of launch.

1. Use of the B–1 for Scientific Flights

The B–1 vehicle is used to put up a more or less standardized Kosmos scientific payload which consists essentially of a short sealed cylinder with hemispheric ends. Most are spin stabilized during launch. Some carry internal chemical batteries only; others have solar cells either on the exterior of the cylinder or on panels that fold out from the body of the spacecraft. The instrumentation and booms, if any, vary with the experiments being conducted. Their weights have never been announced, but probably range from 260 to 425 kilograms. Two had a special stabilization system that depended upon use of the aerodynamics of the atmosphere still present in low orbit enough to influence vehicle performance. An annular ring was extended in orbital flight on telescoping booms well to the rear of the spacecraft. This was successful, but would only work for relatively short-lived low orbits.

Flights made at Kapustin Yar have flown at inclinations close to 49 degrees, or, from 1966 on at about 48.4 degrees. Only a few were announced as to the scientific purpose at the time of launch. An even smaller number of scientific payload launches were made at Plesetsk, either at 71 degrees or at 82 degrees. In more recent years, the Kosmos

name was replaced by Interkosmos because the flights were carrying cooperative experiments of other countries of the Soviet bloc jointly with the Russians. In the B–1 category, these have been phased out recently through a switch of such payloads to use of the larger and more versatile C–1 launch vehicle.

Replicas of many of the B–1 payloads have ultimately been put on display either in Moscow or in international exhibitions.

The table which follows sorts out the B–1 launches by inclination and by orbital characteristics. The mission descriptions represent experiments or instrumentation referred to in the Soviet literature, often with added details or overlapping details becoming available over a period of time.

TABLE 2–2.—IDENTIFIABLE USE OF THE B–1 LAUNCH VEHICLE FOR SCIENTIFIC ORBITAL MISSIONS

Year and Kosmos number	Kapustin Yar 48.4–49°				Plesetsk		Mission description
	Very low	Low	Intermediate	High	71° low	82° low	
1962:							
1			980–217				Electron density, propagation, geomagnetic, solar wind.
2				1,546–212			Electron density, propagation, ion composition, solar UV radiation.
3			720–229				Electron density, propagation, atmospheric density, solar and cosmic radiation.
5				1,600–203			Electron density, atmospheric density, solar and cosmic radiation, geomagnetism.
6		360–274					Cosmic radiation.
8		604–256					Electron density, atmospheric density, micrometeorites.
11			921–245				Atmospheric density, ion density, propagation.
1963:							
14		512–265					Meteorology.
17			788–260				Electron density, atmospheric density, solar and cosmic radiation.
19		519–270					Atmospheric density, cosmic radiation.
23		613–240					Meteorology.
1964:							
25		526–272					Cosmic radiation.
26		402–271					Magnetic fields.
49		490–260					Magnetic fields. UV radiation.
51		554–264					Luminosity of stellar background.
1965:							
53				1,192–227			Cosmic radiation, neutron flux.
97				2,100–220			Quantum generator maser and atomic clock.
1966:							
108			865–227				Electron density, propagation, atmospheric density, solar and cosmic radiation.
135		662–259					Gamma radiation, micrometeorites.
137				1,720–230			Radiation, proton spectrum, charged particles (Cerenkov counter).
1967:							
142				1,362–214			Radio propagation.
149	297–248						Meteorology, radiation gauges, aerostabilized payload.
163		616–261					Cosmic ray telescope.
166		578–283					Solar X-ray, UV, and short wave emissions (spin stabilized).
196			887–225				Atmospheric studies.
1968:							
215		426–261					8-telescope astronomy—visible, IR, UV, X-ray. spectrometer, also ocean surface brightness, photometer of upper atmosphere, emission line of oxygen. (spin stabilized).
219				1,770–222			Electron spectrum of inner belt—magnetometer, scintillation counter, photospectrometer, soft proton spectrometer.

TABLE 2-2.—IDENTIFIABLE USE OF THE B-1 LAUNCH VEHICLE FOR SCIENTIFIC ORBITAL MISSIONS—Con.

Year and Kosmos number	Kapustin Yar 48.4–49° Very low	Low	Intermediate	High	Plesetsk 71° low	82° low	Mission description
225		530–257					Electron flux study of Brazilian anomaly, cosmic rays.
230		580–290					Solar X-ray and UV (spin stabilized).
259				1,353–219			Ionospheric studies, radio propagation.
261					670–217		Atmospheric and aurorae studies—charged particles, plasma, fluxes of soft photoelectrons, spectra of auroral electrons [Bloc cooperation].
262			818–263				Hard radiation intensity (Geiger counters).
1969:							
IK-1		640–260					Solar UV and X-ray, plus effects on upper atmosphere. [Bloc cooperation.]
IK-2				1,200–206			Night ionospheric measures and magnetosphere, concentration of positive ions, electrons, electron temperature [Bloc cooperation].
1970:							
320	342–240						Meteorology, reflected solar radiation, albedo, long wave radiation, cloud cover, aerostabilized payload.
321					507–289		Geomagnetism, ring currents, ionospheric measures.
335		415–254					UV radiation.
348					680–212		Atmospheric and aurorae studies—photo electrons, ion temperatures, horizontal gradients [Bloc cooperation.]
IK-3				1,320–207			Cosmic rays, low frequency fluxes of charged particles, dynamic processes of radiation belts, UV and X-ray, nature and spectrum of electromagnetic oscillations. [Bloc cooperation].
356						600–240	Atmospheric and aurorae studies—radiation.
IK-4		668–263					Radiation flux of whole solar disk, soft and hard X-rays, UV, background of charged particles, optical measures. [Bloc cooperation].
1971: IK-5				1,200–205			Cosmic rays and lower frequencies, fluxes of charged particles. [Bloc cooperation].
1972:							
481					540–279		Geomagnetic.
IK-7		568–267					Solar UV and X-rays. [Bloc cooperation].
IK-8					679–214		Ionospheric electrons and temperatures, protons, ion concentration. [Bloc cooperation].
1973: IK-9				1,551–202			Solar radiation and ionospheric radio waves excitation by solar corona. [Bloc cooperation].

NOTES

1. The groupings by apogee and perigee are somewhat arbitrary, but may be compared with groupings used for military missions with similar externals and launched also by the B-1 vehicle.
2. The mission descriptions, often issued piecemeal even years after the flight occurred are abbreviated, and to a degree overlap, or mix missions and instrumentation, but they give a general indication as to the areas of interest for each flight.
3. It will be noted that Interkosmos flight designations appear as well as Kosmos flights. The Soviet Bloc cooperative flights are abbreviated with the prefix initials IK. Kosmos 261 and 348 although not given IK numbers were also cooperative flights. Presumably they were assigned Kosmos designators because at the time non-Soviet participants were not permitted to visit the Plesetsk launch site where these were sent up.

SOURCES: Basic flight data from Soviet TASS bulletins. Followup mission descriptions sometimes appear as articles in the regular Soviet press. Others appear in references in the scientific literature even years later; and some references are found one or more years later in Soviet reports to COSPAR (Committee on Space Research, International Council of Scientific Unions).

2. Use of the C–1 Scientific Flights

The B–1 launch vehicle came into use in 1962, and the C–1 came into use in 1964. But while the B–1 was used for scientific flights from the outset, the C–1 was restricted to military missions until 1970. This may be why the Russians released pictures, replicas, and measurements of the B–1 in 1967, but even today have not done the same for the C–1, but whose picture without other details finally was made public in 1975.

The last use of a B–1 for a scientific mission came in 1973, and the growth in the use of the C–1 has now completed the phased shift to the larger, more versatile vehicle.

The preceding section noted that in some cases, it has not been possible to establish a B–1 flight as scientific rather than military until well after the event, depending upon the appearance of references in the scientific literature. Most C–1 flights can be catalogued as to military versus civilian use on the basis of their announced flight parameters, but there are exceptions, and hence any tabulation may need revision over time. For example, Kosmos 381 was promptly announced as a scientific topside sounder, and many results have been published. Kosmos 385 has almost the same kind of orbit, but nothing has been said of it, and it was followed by other flights which have been judged to be navigation satellites.

At least two C–1 launches (Kosmos 426 and 546) look from their externals as if they should be scientific flights. Will the literature eventually reflect this, or are they instrumentation failures, or are they unidentified military missions? Another small group of exceptional flights with the C–1 could be scientific when and if results of experiments are published, but have been counted as military even though not fitting the wholly regular and repetitive flights in the ferret, navigation, and store-dump communications categories. Since the B–1 has been replaced by the C–1 for scientific missions, the suspicion arises that some of the minor military flights which look similar to scientific missions may also have been upgraded from use of the B–1 to use of the C–1. This leaves us, therefore, several missions which do not match other scientific missions or regular military C–1 missions, but two of them match the kinds of orbits used for minor military B–1 mission. These are Kosmos 660 and Kosmos 687. They may prove later to be scientific. Kosmos 708 also does not fit any other pattern: it has the apogee and perigee of the navigation or geodesy series, but is at a unique inclination. It could be scientific. Kosmos 752 is also anomalous, but will be treated as probably military until shown otherwise by Soviet announcement.

Both the French Oreol (Aureole) payloads and the Indian Ariabat (Aryabhata) payload have used the C–1 launch vehicle.

The table which follows summarizes the tentative assignment of C–1 flights to the scientific category. The table excludes Kosmos 256 which carried only supplemental scientific experiments to its main military missions and Kosmos 610 for the same reason.

TABLE 2-3.—IDENTIFIABLE USE OF THE C-1 LAUNCH VEHICLE FOR SCIENTIFIC ORBITAL MISSIONS

Year and Kosmos number	Kapustin Yar 50.7°	Plesetsk 69.2°	Plesetsk 74° circular	Plesetsk 74° eccentric	Plesetsk 83°	Mission
1970:						
378				1,763–241		Ionospheric studies, plasmas, leaking of charged particles of different energies.
381			1,023–985			Pulsed topside sounder on 20 frequencies and measuring electron flux.
1971:						
426				2,012–394		Possible ionospheric studies.
461		524–490				Intensity, spectral composition, distribution, angular direction of gamma radiation.
Oreol 1				2,500–410		Wideband spectrum of protons and electrons, proton intensity, ion composition of atmosphere [French].
1973:						
546	630–585					Possible solar studies.
IK-10				1,477–265		Particle temperatures, energies, concentrations—electrons, ions, neutral atoms, magnetic fields, low frequency oscillations in ionosphere [Bloc cooperation].
Oreol 2				1,995–407		Charged particles—protons, electrons ion composition, numbers, energy distribution, auroras of upper atmosphere [French].
1974:						
IK-11	526–484					Solar UV and X-ray, upper atmosphere study [Bloc cooperation].
IK-12				708–264		Atmospheric composition and structure—numbers, character, energies in ionosphere, micrometeorites [Bloc cooperation].
1975:						
IK-13					1,714–296	Magnetosphere dynamics, processes of polar ionosphere, low frequency electromagnetic waves [Bloc cooperation].
Ariabat	619–563					X-ray astonomy, solar gamma and neutrons, particle flows and radiation in ionosphere [Indian].
IK-14				1,707–345		Low-frequency electromagnetic wave fluctuations in magnetosphere, structure of ionosphere, micrometeoritic intensity [Bloc cooperation].

NOTES

1. To the extent possible, the scientific missions using the C-1 launch vehicle have been isolated for inclusion in this table. Two C-1 flights do not seem to fit in the military category, yet no scientific results have been found published in the literature. Kosmos 426 which roughly resembles Kosmos 378 may belong in the same miscellaneous category as Kosmos 660, or it may be a payload whose instrumentation failed to function. Kosmos 546 somewhat resembles Interkosmos 11 but no findings have been published, so may be a scientific payload whose instrumentation failed to function.
2. Two other payloads launched by the C-1 and whose external patterns are wholly consistent with other C-1 flights strongly believed to be military seem to have carried supplemental experiments which are scientific in nature. Kosmos 256 which may be a navigation or geodetic satellite also returned data on solar and cosmic radiation. Kosmos 610 which may be an electronic ferret or elint flight also is said to have carried a biological experiment.
3. The flights included have been grouped by year, inclination, and type of orbit, with mission data summarized from widely scattered, sometimes overlapping references in Soviet scientific journals and COSPAR reports.
4. Interkosmos flights are abbreviated as IK prefix initials plus the number. These are cooperative flights with countries in the Soviet Bloc. Additionally the table reflects French and Indian payloads launched on the C-1 vehicle.

SOURCES: Basic flight data from Soviet TASS bulletins. Followup mission descriptions sometimes appear in articles in the regular Soviet press. Others appear in references in the scientific literature even years later; and some references are found one or more years later in Soviet reports to COSPAR.

3. *Use of the A-1 and A-2 for Scientific Supplemental Payloads*

In addition to flights which serve primarily a scientific purpose, the Russians have used spare capacity on military flights, often allowing recovery of the data in the case of military photographic missions, which would probably not justify their cost if operated as separate scientific missions.

But analysis of these flights is difficult, and is dependent upon Soviet announcements often which are not available until years after the flight. Analysis is difficult because in many cases the flights are launched into low Earth orbit, and after some days are recalled, and no external clue is revealed that the same flight is doing something else which may be scientific.

As the Russians have ultimately revealed something of the nature of supplemental experiments, one can retrospectly draw some tentative conclusions.

For example, one series of military photographic flights also gave engineering support to the techniques of launch, control, and recovery of manned flights to follow. Another group carried sensors and television cameras that gathered weather data which later led to a separate series of weather satellites in sustained, non-recoverable flight.

A working hypothesis has been that the military recoverable flights were essentially unmanned Vostok capsules, carrying camera systems instead of human crews. This belief was encouraged by the fact that an occasional Soviet photograph in a factory showed more Vostok capsules being manufactured than were ever required by the flights in the Vostok program that occurred. Also, just as most manned flights have been preceded by unmanned precursors, some of the Vostoks were preceded not only by the dog-carrying Korabl Sputniks, but also by military Kosmos flights which stayed up the same number of days as Vostoks which shortly followed.

If this is correct, then the military Kosmos payloads which carry supplemental experiments probably carry them for the most part in the main recoverable capsule. The military flights for some years were typically of about eight days duration. However, in 1968, a change occurred. Military flights started to stay up typically 12 or 13 days, and a very considerable number of them began to separate a component part toward the end of the flight. The Royal Aircraft Establishment (RAE) estimates this type of separated object as being about 2 meters in diameter. This raises a real possibility that the Vostok shell has been replaced by a Soyuz shell, consisting of a recoverable module with some lifting, steering capability during reentry, a more versatile service module which could have solar panels but may operate with chemical batteries alone as do the Soyuz ferry craft which went to Salyut 3 and 4, and also a third compartment equivalent to the orbital work compartment of Soyuz, and perhaps this is what is abandoned by most of the military recoverable photographic missions of recent years. If so, then the main cameras and film serving their military purpose are contained in the recovery module, while supplemental payloads are carried in the third compartment left in orbit, soon to decay without recovery. Some of these capsules seem to be an extra maneuvering unit which accounts for the many orbital adjustments these flights often make. Others of these may contain the supplemental scientific payloads. As such, they add to our statistics on number of functional payloads the Russians put up. The Russians do not help us because they have never discussed or otherwise disclosed what they do on these large payload military flights which constitute the largest single element in the Soviet program.

Analysis is difficult in the absence of Soviet information. The RAE lists all the capsules, not distinguishing between possible maneuvering units and containers for supplemental payloads. There is a good correlation among the appearance of these capsules late in flight, the changes of orbit during flight signifying maneuvers, and the collection of data on telemetry and beacon signals by Geoffrey E. Perry of the Kettering Group. Perry's data show which ones should maneuver, and they usually do, which ones should not maneuver and not separate

a capsule, also borne out, and finally those that will not maneuver but will separate a capsule. These several bits of analytical procedure make it possible to sort out a tentative list of flights on which there may be supplemental scientific payloads, and to a point this works very well. By waiting patiently for the annual COSPAR report, one can learn from the Russians that indeed some of the flights Perry tagged did carry scientific payloads as well as their main military photograph system.

But there are complications. A few of the maneuvering military payloads that cast loose a capsule that hypothesis says are maneuvering engines also turn out to have scientific experiments on board. Are they carried in the capsule or in the main recoverable portion? Some capsules abandoned by non-maneuvering military payloads never have later scientific accounts of experiments. Perhaps some of the supplemental payloads are military instead of scientific.

On the basis of all this foregoing discussion, it will be recognized how tentative the list which follows must remain until the Russians make a fuller explanation. It does at least provide a starting place for better analyses in the future.

TABLE 2-4.—IDENTIFIABLE AND POSSIBLE USE OF THE A-1 AND A-2 LAUNCH VEHICLES FOR KOSMOS SCIENTIFIC AND SUPPLEMENTAL PAYLOADS

Year and Kosmos number	Launch vehicle	Payload type	Apogee and Perigee	Inclination	Pickaback or maneuvering eng.	RAE capsule report	Mission category	Mission description and notes
1962:								
4	A-1	V	330-298	65.0	0	0	BGW	Geomagnetic sensors, radiation detectors.
7	A-1	V	369-210	65.0	0	0	BGW	Geomagnetic sensors, radiation detectors.
9	A-1	V	358-301	65.0	0	0	W	Weather experiments.
1963: 15	A-1	V	371-173	65.0		0	W	Weather experiments.
1964:								
41	A-2-e		39,855-394	64.0	0	0	G	Proton, electron intensity in outer radiation belt.
45	A-2	V	327-206	64.9	0	0	W	Weather experiments.
1965:								
65	A-2	V	342-210	65.0	0	0	W	Weather experiments, Earth UV.
92	A-2	V	353-212	65.0	0	0	WB	Weather and biology experiments.
94	A-2	V	293-211	65.0	0	0	B	Biology experiments.
1966:								
109	A-2	V	309-209	65.0	0	0	B	Biology experiments.
110	A-2	V	904-187	51.9	0	0	B	Wholly devoted to long duration biology with dogs later recovered.
122	A-1		625-625	65.0	0	0	WG	Supplemental IR studies.
125	A-1-m		250-250	65.0	0	0	E	Ion orientation system test.
134	A-2	V	319-214	65.0	0	0	G	Proton, electron, radiation counters.
136	A-1	V	305-193	64.6	0	0	G	Radiation studies of protons, electrons.
1967:								
143	A-1	V	302-204	65.0	0	0	G	Charged particles study.
159	A-2-e		60,600-380	51.8	0	0	G	Possible, but may relate to other programs.
184	A-1		635-635	81.2	0	0	E	Ion orientation system test.
1968:								
208	A-2	S	305-207	65.0	P	C	G	X-ray and gamma flux.
224	A-2	V	270-200	51.8	0	0	G	Atmospheric composition, luminescence.
228	A-2	S	259-206	51.6	P	C	G	Cosmic rays, ionizing radiation.
243	A-2	S	319-210	71.3	P	C	G	Radio telescope passive microwave to study heat emissions of Earth for soil humidity and ice thickness, etc.
251	A-2	S	270-198	65.0	M	C	G	Extragalactic gamma ray sources.
1969:								
264	A-2	S	330-119	70.0	M	C	G	Extragalactic gamma ray sources.
274	A-2	V	323-213	65.0	0	0	G	Neutral and ion composition of atmosphere.
279	A-2	V	280-194	51.8	0	0	E	Ion orientation system test.
280	A-2	S	272-206	51.6	M	C	G	Charged particles study.
293	A-2	S	270-208	51.8	P?	0	?	Telemetry indicates should have had pickaback.
309	A-2	S	384-203	65.4	P?	0	?	Telemetry like Kosmos 208.
317	A-2	S	302-209	65.4	M	C	G	Charged particles study.
1970:								
368	A-2	S	421-212	65.0	P	C	B	Biology and radiation experiments.
384	A-2	S	314-212	72.9	P	C	G	Super high radio frequency Earth emissions.
1971:								
410	A-2	S	300-207	65.0	P	C	G	Particle fluxes, excess radiation.
428	A-2	S	271-208	51.8	P	C	G	Electron flux, gamma flux, cosmic rays.
443	A-2	S	325-211	65.4	P	C	G	Radiation flux, particles.
470	A-2	S	272-195	65.4	P	C	?	
1972:								
477	A-2	S	328-212	72.9	P	C	G	Particle fluxes, excess radiation.
484	A-2	S	236-203	81.3	P	C	G	Cosmic rays, solar radiation.

490	A-2	S	310-212	65.4	P	C	G	2 telescopes for high energy electron fluxes, primary cosmic rays.
502	A-2	S	284-206	65.4	P	C	?	
518	A-2	S	330-208	72.9	P	C	?	
525	A-2	S	292-208	65.4	P	C	?	
541	A-2	S	371-242	81.4	P	C	?	
1973:								
552	A-2	S	337-211	72.9	P	C	?	
555	A-2	S	253-216	81.3	P	C	?	
561	A-2	S	317-215	65.4	P	C	G	Gamma ray telescope for galactic studies.
576	A-2	S	356-212	72.9	P	C	?	
605	A-2	S	421-221	62.8	?	C	B	Wholly devoted to a variety of biological experiments for long duration.
616	A-2	S	355-214	72.9	P	C	?	
1974:								
629	A-2	S	315-202	62.8	P	C	?	
635	A-2	S	350-212	72.9	P	C	?	
664	A-2	S	364-212	72.9	P	C	?	
669	A-2	S	244-210	81.3	P	C	?	
690	A-2	S	389-223	62.8	O?	0	B	Wholly devoted to a variety of biolcgical experiments for long duration.
692	A-2	S	315-201	62.8	P	C	?	
693	A-2	S	271-215	81.3	P	C	?	
697	A-2	S	415-182	62.8	P	C	?	
1975:								
720	A-2	S	283-223	62.8	P	C	?	
721	A-2	S	241-210	81.3	P	C	?	
728	A-2	S	350-211	72.8	P	C	?	
731	A-2	S	313-207	65.0	P	C	?	
747	A-2	S	309-197	62.8	P	C	?	
759	A-2	S	281-234	62.8	P	C	?	
769	A-2	S	331-211	72.9	P	C	?	
776	A-2	S	310-203	62.8	P	C	?	
780	A-2	S	298-206	65.0	P		?	
782	A-2	S	405-227	62.8	?		B	Wholly devoted to a variety of biological experiments for long duration.
784	A-2	S	252-216	81.3	P		?	

NOTES

1. This table includes all the Kosmos flights launched by A class launch vehicles which are known or believed to have carried scientific payloads. Most of them are military photographic recoverable missions, except as otherwise indicated. Flights which were wholly devoted to biological missions were Kosmos 110, 605, 690 and 782. Kosmos 41 was a communications satellite precursor which also carried scientific or engineering test equipment. Kosmos 159 was devoted to what may have been a radiation belt and solar study mission, but the absence of published findings may require its reclassification as an early warning military mission. Kosmos 122 and 184 were weather satellites also carrying geophysical experiments. Kosmos 125 was a military test vehicle which also carried an engineering test of ion orientation equipment. Any supplemental scientific or engineering experiments on precursors to manned flights have not been included in the table.

2. The column showing payload type singles out those which may have used the basic structure of Vostok/Voskhod, symbolized by V; and assumes that the Russians may have phased into use starting with Kosmos 208 the basic structure of Soyuz, perhaps sometimes with an adaptation of the orbital work compartment, and sometimes without it, all symbolized by S. The assumption of Soyuz use may be unfounded.

3. Apogee and perigee are shown in kilometers. Inclination is in degrees.

4. When the Royal Aircraft Establishment (RAE) reports the presence of a separated capsule, this is symbolized by C. The RAE does not distinguish between separated maneuvering engines and pickaback payload capsules, both of which presumably use or take the place of a Soyuz orbital work compartment, and which are separated from the rest of the Kosmos (Soyuz equivalent) late in the flight. Based upon either evidence of maneuvers or on telemetry formats, a column attempts to show which may be pickabacks (P), which maneuvering engines (M), and when nothing has been reported as separating (O).

5. For quick reference, mission categories also have been indicated for these scientific roles: B–biology, W–weather, G–geophysics, E–engineering test.

6. Mission descriptions are abbreviated accounts as eventually found in the Soviet literature, or as inferred in a few cases.

7. Most missions were not identified at the time of the flight, and in some cases years passed before the scientific literature revealed their purposes. However, now there are so many which are unexplained that one wonders whether even the pickabacks are increasingly used for classified military purposes, much as the B-1 launch vehicles started out being used for scientific purposes and then phased over to military use.

8. Among scientific activities under the Kosmos label not included in the table are the following: Of manned precursors using the A-2: Kosmos 140 and 213 conducted tests with superconducting magnetic coils. Of manned precursors using the A-2-m: Kosmos 379, 398, and 434 all measured ion concentrations in space. Of the C-1 flights, Kosmos 256, a navigation mission also carried a solar and cosmic ray experiment, and Kosmos 610, an electronic ferret, carried a biological experiment.

SOURCES: **Basic flight data are from Soviet TASS bulletins; vehicle types are based on RAE optical and radar studies; payload types are surmised from telemetry received by the Kettering Group, maneuvers, and separated objects. Mission listings have emerged gradually, mostly from Soviet scientific journals.**

F. KOSMOS MILITARY FLIGHTS

The text has already explained that most Kosmos flights serve military purposes. These are treated in detail in a separate chapter, and have been discussed here only in the context of identifying which are which and also those military flights which carry supplemental scientific payloads.

G. PRECURSOR FLIGHTS WITHIN KOSMOS

All that is necessary here is to provide a checklist of Kosmos flights which almost certainly were engineering tests and development flights leading to operational systems which carried other names. This class in some small degree may overflap space failures, which will be identified presently.

Voskhod Precursors (A–2 vehicles)

Kosmos 47	Kosmos 57

Soyuz Precursors (A–2 vehicles)

Kosmos 133	Kosmos 573
Kosmos 140	Kosmos 613
Kosmos 186	Kosmos 638
Kosmos 188	Kosmos 656
Kosmos 212	Kosmos 670
Kosmos 213	Kosmos 672
Kosmos 238	Kosmos 772
Kosmos 496	

Zond Precursors (D–1–e vehicles)

Kosmos 146	Kosmos 154

Man-Related Special Precursors

Kosmos 379 (A–2–m vehicle)	Kosmos 434 (A–2–m vehicle)
Kosmos 398 (A–2–m vehicle)	Kosmos 382 (D–1–m vehicle)

Venus Precursor (A–2–e vehicle)

Kosmos 21

Meteor Precursors (A–1 vehicles)

Kosmos 44	Kosmos 144
Kosmos 58	Kosmos 156
Kosmos 100	Kosmos 184
Kosmos 118	Kosmos 206
Kosmos 122	Kosmos 226

Molniya 1 Precursors

Kosmos 41 (A–2–e vehicle)	Kosmos 637 (D–1–e vehicle)

H. FLIGHT MISSION FAILURES DISGUISED AS KOSMOS

These are discussed in the context of their missions and all that is needed here is a checklist of mission failures which received Kosmos names.

Luna Failures

Kosmos 60 (A–2–e vehicle)	Kosmos 300 (D–1–e vehicle)
Kosmos 111 (A–2–e vehicle)	Kosmos 305 (D–1–e vehicle)

Venus Failures (A–2–e vehicle)

Kosmos 27
Kosmos 96
Kosmos 167
Kosmos 359
Kosmos 482

Mars Failure (D–1–e vehicle)

Kosmos 419

Salyut Failure (D–1 vehicle)

Kosmos 557

I. SUMMARY ON KOSMOS FLIGHTS

So much detail has been provided in the sections above that it may be helpful to recapitulate on the number of Soviet flights which have carried the name Kosmos, have carried other names, or have been unacknowledged, by various classes of missions for the time span 1957–1975 inclusive. Such a table follows:

TABLE 2-5.—SUMMARY RECAPITULATION OF KOSMOS, OTHER NAME, AND UNACKNOWLEDGED SOVIET SPACE PAYLOADS BY MISSION CATEGORY, 1957–1975

Mission	Kosmos	Other name	Unacknowledged	Total
PRIMARILY CIVILIAN				
Earth Orbital Science	40	31	40	111
Earth Orbital Engineering		2		2
Vehicle Tests	2	2		4
Communications	2	52		54
Weather	14	24		38
Geodesy				
Earth Resources				
Earth Orbital Man-Related or Biology	25	9		34
Earth Orbital Manned		29		29
Lunar Man-Related or Biology	3	5		8
Lunar Manned				
Moon (Unmanned)	4	23	5	32
Venus, Mercury	6	12	5	23
Mars, Jupiter, Saturn	1	9	6	16
Interplanetary Medium				
PRIMARILY MILITARY				
Military Recoverable Observation	328			328
Mapping and Geodesy				
Minor Military (Environmental Monitoring, Radar Calibration, Electronic ferret?)	94			94
Elint, Ferret	42			42
Navigation and Geodesy	46			46
Military communications (Store-Dump)	128			128
Early Warning	7			7
Fractional Orbit Bombardment System	16		2	18
Ocean Surveillance	12			12
Inspection Targets	9			9
Inspector Destructors	7			7
Subtotal	786	198	58	1,042
Orbital Launch Platforms		1	134	135
Total	786	199	192	1,177

NOTES

1. The headings are those used in Table 2 of Chapter One, to increase comparability of the two tables.
2. The count of Kosmos flights matches the total number of Kosmos numbers announced by the Russians.
3. Other names are those also shown in Table 4 of Chapter One, and 25 such have been introduced during the course of the Soviet space program.
3. The unacknowledged payloads include 8 which were primarily missions whose very existence has never been acknowledged by the Russians, 16 which were planetary landers or lunar sample returners, and 40 possible pickabacks.
4. The table shows the mixed use of Kosmos for civilian and military purposes, but the more dominant use of the name for military missions.

SOURCES: Data are derived from Appendix A, supplemented from the text of the study.

J. THE INTERKOSMOS PROGRAM

1. Overview of All International Orbital Flights

While the Soviet program of international cooperation in space flight started later than that of the United States, it has finally achieved fairly respectable scope. The principal organization for conducting shared experimentation has been the Interkosmos Office of Moscow, headed by Academician Boris N. Petrov. Most of these flights carry the designator Interkosmos, and are an extension of the scientific portion of the regular Kosmos series. For this reason, the table of Kosmos scientific flights, already presented, summarized in that context the experiments to the extent known of the Interkosmos flights as well.

Table 2–6 which follows puts these Interkosmos flights into the context of all the known international cooperative flights to give a clearer impression of their total scope. Another chapter of this report will discuss the details of negotiation and operation of the cooperative programs, while this section is more concerned with the science and technology of Interkosmos, and there will follow in the next section similar details on other flights not carrying the Interkosmos label.

It will be noted from the table that Interkosmos originally used the B–1 vehicle from Kapustin Yar. Then one time, for Interkosmos 6, it used the A–2 for a recoverable flight from Tyuratam, and by Interkosmos 8 added use of the Plesetsk launch site. Actually cooperative flights from Plesetsk had come earlier, but at that time Plesetsk was not open even to Soviet Bloc technicians, so the payloads were labeled Kosmos 261 and 348. Starting with Interkosmos 10, the C–1 vehicle, with higher capabilities, displaced the smaller B–1, both from Plesetsk and Kapustin Yar.

TABLE 2-6.—SUMMARY LIST OF SOVIET ORBITAL AND ESCAPE FLIGHTS WHICH CARRIED EXPERIMENTS OF OTHER NATIONS

Launch date	Flight name	Launch vehicle	Launch site	Apogee	Perigee	Inclination	Hardware participating nations
1968							
Dec. 19	Kosmos 261	B-1	PL	670	217	71	Bulgaria, Czech., GDR, Hungary, Poland, Romania, U.S.S.R.
1969							
Oct. 14	IK-1	B-1	KY	640	260	48.4	Czech., GDR, U.S.S.R.
Dec. 25	IK-2	B-1	KY	1,200	206	48.4	Bulgaria, Czech., GDR, U.S.S.R.
1970							
June 13	Kosmos 348	B-1	PL	680	212	71	Bulgaria, Czech., GDR, Hungary, Poland, Romania, U.S.S.R.
Aug. 7	IK-3	B-1	KY	1,320	207	49	Czech., U.S.S.R.
Oct. 14	IK-4	B-1	KY	668	263	48.5	Czech., GDR, U.S.S.R.
Nov. 10	Luna 17	D-1-e	TT	Lunar lander			France, U.S.S.R.
1971							
May 28	Mars 3	D-1-e	TT	Mars orbiter			France, U.S.S.R.
Dec. 2	IK-5	B-1	KY	1,200	205	48.4	Czech., U.S.S.R.
Dec. 27	Oreol 1	C-1	PL	2,500	410	74	France, U.S.S.R.
1972							
Apr. 4	MAS-1	A-2-e	PL	39,260	480	65.6	France (pickaback on U.S.S.R.).
Apr. 7	IK-6	A-2	TT	256	203	51.8	Czech., Hungary, Mongolia, Poland, Romania, U.S.S.R.
June 29	Prognoz 2	A-2-e	TT	200,000	550	65	France, U.S.S.R.
June 30	IK-7	B-1	KY	568	267	48.4	Czech., GDR, U.S.S.R.
Nov. 30	IK-8	B-1	PL	679	214	71	Bulgaria, Czech., GDR, U.S.S.R.
1973							
Jan. 8	Luna 21	D-1-e	TT	Lunar lander			France, U.S.S.R.
Apr. 19	IK-9	B-1	KY	1,551	202	48.5	Czech., Poland, U.S.S.R.
Aug. 5	Mars 6	D-1-e	TT	Mars lander			France, U.S.S.R.
Aug. 9	Mars 7	D-1-e	TT	Mars lander			France, U.S.S.R.
Oct. 31	IK-10	C-1	PL	1,477	264	74	Czech., GDR, Ukraine, U.S.S.R.
Dec. 26	Oreol 2	C-1	PL	1,995	407	74	France, U.S.S.R.
1974							
May 17	IK-11	C-1	KY	526	484	50.7	Czech., GDR, U.S.S.R.
Oct. 31	IK-12	C-1	PL	708	264	74.1	Bulgaria, Czech., GDR, Hungary, Romania, U.S.S.R.

TABLE 2-6.—SUMMARY LIST OF SOVIET ORBITAL AND ESCAPE FLIGHTS WHICH CARRIED EXPERIMENTS OF OTHER NATIONS—Continued

Launch date	Flight name	Launch vehicle	Launch site	Apogee	Perigee	Inclination	Hardware participating nations
1975							
Mar. 27	IK-13	C-1	PL	1,714	296	83	Czech., U.S.S.R.
Apr. 19	Ariabat	C-1	KY	619	563	50.7	India, U.S.S.R.
June 5	MAS-2	A-2-e	PL	40,890	450	63	France (pickaback on U.S.S.R.).
July 15	Soyuz 19	A-2	TT	225	223	51.8	U.S.S.R., United States.
Nov.	Kosmos 782	A-2	PL	405	227	62.8	U.S.S.R., United States, Czech., France.

NOTES

1. The table includes only flights which reached orbit or escape; it does not include unannounced launch failures, or cooperative rocket probes such as Vertikal 1, 2, and 3, or other experiments such as Araks, which was launched on French Eridan rockets on Kerguelen for conjugate point experiments.

2. The abbreviation IK signifies Interkosmos. The abbreviation MAS refers to "minor autonomous satellite," which the French list as SRET. Oreol is called Aureole by the French. Ariabat is called Aryabhata by the Indians.

3. The French contributions to Luna flights have been laser corner reflectors mounted on Lunokhod surface rovers. The French contributions to Mars flights have been solar studies experiments either Stereo or Zhemo, used during the course of the flight toward Mars.

4. In addition to the nations contributing hardware, often most of the Soviet Bloc countries have participated in reading out data from the Interkosmos or Kosmos cooperative flights.

5. Apogee and perigee are in kilometers; inclination is in degrees.

SOURCES: Flight data are from Soviet TASS bulletins. Launch vehicle and launch site identifications are from Appendix A. Participating country lists are from either TASS or review articles in the Soviet general press.

2. Interkosmos Flights of the Period 1968–1970

Kosmos 261 was identified as a cooperative flight of seven Soviet Bloc countries to study the upper atmosphere and the nature of the northern lights, including study of electrons and protons, electronics of superthermal energy, and changes in the density of the atmosphere during auroral activity. This flight in late 1968, and its follow-on in 1970, called Kosmos 348, were from Plesetsk, and at the time, non-Soviet technicians or scientists were not allowed to be present for the launches.

When the more open program began in 1969, including introduction of the designator Interkosmos, the flights were from Kapustin Yar, and representatives of the cooperating countries were able to attend the launches, with their national flags displayed, presumably adding to the festive air.

Interkosmos 1 was launched on October 14, 1969, with equipment from the German Democratic Republic, the Soviet Union, and Czechoslovakia. The countries additionally participating in readout of data were Bulgaria, Hungary, Poland, and Romania. All seven flags were flown. The purpose of the flight was to study solar ultraviolet and X-ray radiation and the effects of these on the structure of the Earth's upper atmosphere.

Interkosmos 2 followed on December 25, 1969 with instruments from Bulgaria, Czechoslovakia, the German Democratic Republic and the Soviet Union. Cuba joined the list of countries sharing in the readout. The flight studied the concentration of electrons and positive ions of the Earth's ionosphere, and electronic temperature near the payload, as well as mean electron concentration between the payload and the ground receiving stations. The principal tracking stations were 2 in Poland and 7 in the U.S.S.R.

Interkosmos 3 was launched on August 7, 1970 with Czechoslovakian and Soviet experiments. It studied the interactions between solar activity and the radiation belts of Earth, including the nature and spectrum of low frequency electromagnetic oscillations in the upper ionosphere.

Interkosmos 4 was launched on October 14, 1970 with equipment from the German Democratic Republic, Czechoslovakia, and the Soviet Union. It was in effect a repeat of Interkosmos 1 but with more sensitive instruments to measure a wider range of energies.

3. Interkosmos 5

Interkosmos 5 was launched on December 2, 1971 at Kapustin Yar, using the B–1 launch vehicle. It carried equipment built in Czechoslovakia and the Soviet Union in continuation of the work begun with Interkosmos 3. It studied the compositon and variations in streams of charged particles over time; recorded and analyzed the spectrum of low frequency electromagnetic waves in the range of 70 Hz to 20 kHz. The work was coordinated with synoptic readings taken at ground stations in the cooperating countries of the Interkosmos agreement. Actual flight operations were jointly controlled by the Russians and the Czechs. Ground stations received data from the satellite in the Soviet Union, Czechoslovakia, and the German Democratic Republic. Where the predecessor payload had carried about 1,000 transistors and diodes, it had now been possible to simplify the circuits to only about 500.

4. Interkosmos 6

Interkosmos 6 was launched on April 7, 1972, for the only time in this program using the large A–2 launch vehicle, from Tyuratam, in order to carry a much greater weight and to permit recovery of the payload. The main purpose was to study cosmic rays, particularly primaries in the energy range of 10^{12} to 10^{13} electron volts, and to determine their chemical composition and energy spectrum. Additionally, the craft was to measure meteoritic particles in near-Earth space. In order to measure the cosmic rays, the payload carried a photoemulsion unit and an ionization calorimeter, weighing a total of 1,070 kilograms, manufactured in the Soviet Union to specifications developed in Hungary, Mongolia, Poland, Romania, the Soviet Union, and Czechoslovakia. The meteorite experiment was developed and manufactured jointly in Hungary, the Soviet Union, and Czechoslovakia.

After launch, the payload was oriented to point toward the oncoming streams of particles. As the flight proceeded, and data were received, the instrumentation was calibrated and adjusted to maximize the accuracy of the data recorded. After four days, the flight was recalled to Earth, and recovered. The block of material was shipped to Dubna for detailed analysis. Later, it was a surprise when the trace of a 1,000-billion electron volt particle was found in the block.

A year later, more details were provided. The stack of nuclear photoemulsion material had a volume of 45 liters, consisting of 805 layers each measuring 600 by 200 millimeters with a thickness of 450 μm. Under the main stack were additional layers to measure electron-photon showers. Two spark chambers monitored the stack. The side walls of the stack had coordinate marks so that stereo-photographs could be taken of the path of any particles with an accuracy of 1 mm. A scintillation counter participated in the control of registry and indicated the charge of the entering particles, to distinguish among protons, alpha particles, and heavy nuclei. By having ten separate sections, it was possible to get some spatial resolution of the particles. An auxiliary scintillation counter helped distinguish between transiting primary particles and the shower of secondary particles. It took two months to develop the entire stack at Dubna.

5. Interkosmos 7

Interkosmos 7 was launched on June 30, 1972 in a continuation of the work begun by Interkosmos 1 and 4. The equipment was built in the German Democratic Republic, Czechoslovakia, and the Soviet Union. All three countries shared in controlling the satellite in flight. The instrumentation measured short wave solar radiation in the range of 1,200 to 1,300 angstroms, which do not reach the surface of the Earth, being absorbed by molecules of oxygen. Other instruments measured hard X-rays from the Sun, which also typically are absorbed in the atmosphere. By measuring these, many solar flares were found that are missed by terrestrial observatories. Six Soviet Bloc countries carried out studies in parallel with the flight of Interkosmos 7.

6. Interkosmos 8

Interkosmos 8 was the first flight of the Interkosmos name to be launched at Plesetsk, which occurred on December 1, 1972. It carried equipment as follows: an ion trap and Langmuir probe from Bulgaria,

a Mayak transmitter and recorder from the German Democratic Republic, a high frequency probe from Czechoslovakia, and an ionospheric gas discharge counter and other equipment from the Soviet Union. The equipment was designed to record streams of electrons with an energy in excess of 40 kiloelectron volts, and protons with an energy of more than one megaelectron volts. Specialists of all four countries were at the launch, signaling the greater openness about Plesetsk which has yet to be identified as a launch site in any Soviet public release.

7. Interkosmos—Kopernik 500

In honor of the 500th birthday of Copernicus, the number 9 was not associated with this payload, but the next in sequence became number 10 on its later launch. This ninth launch came April 19, 1973 at Kapustin Yar.

This payload carried equipment to measure solar radiation and the ionosphere. It was developed jointly by the Soviet Union and Poland. The telemetry system was Czechoslovakian. The instrumentation measured sporadic changes in radio waves of decameter range. (0.6 to 6.0 MHz). The radio spectrograph was built in Poland, and low frequency-high frequency ionospheric probes were built in the Soviet Union. Data were received at ground stations in the Soviet Union and in Czechoslovakia. Simultaneous ground observations were made in the participating Soviet Bloc countries.

8. Interkosmos 10

Interkosmos 10 was the first to use the C–1 class of launch vehicle in the Interkosmos series. It was launched at Plesetsk October 30, 1973. It carried instrumentation to determine the concentration and temperature of ionospheric electrons, using equipment from the German Democratic Republic and Soviet Union; to measure magnetic field variation, electric fields in the range of 0.7 to 70 Hertz, and electron, ion, and neutral atom fluxes in the range of 0.05 to 20 kiloelectron volts with Soviet apparatus; and to study low frequency electric oscillations of plasma in the range of 20 to 22 kiloHertz (designed and built in Czechoslovakia). It carried a Czech telemetry system and Soviet tape recording systems. Ukrainian experiments also were carried.

B. N. Petrov saw the flight initiating a new stage beyond exploratory experiments to making a concentrated attack on complex issues. He said the synoptic recording of much data would increase the value of the results 100-fold. Flight of the satellite was coordinated with launches of German-Soviet weather rockets.

9. Interkosmos 11

Interkosmos 11 was launched May 17, 1974 as the first C–1 Interkosmos launch at Kapustin Yar. It continued studies of the solar ultraviolet and X-ray radiation, and interactions with the upper atmosphere. The experiments were provided by the German Democratic Republic, the Soviet Union, and Czechoslovakia. Again, ground stations in Soviet Bloc nations made synoptic readings.

10. Interkosmos 12

Interkosmos 12 was launched October 31, 1974 at Plesetsk to continue studies of the atmosphere and ionosphere and flow of micro-

meteorites. Instruments were prepared in Bulgaria, Hungary, the German Democratic Republic, Romania, the Soviet Union, and Czechoslovakia. The participating nations sent representatives to the launch, and tracking was done in Bulgaria, the German Democratic Republic, Poland, and Czechoslovakia, as well as the Soviet Union. The equipment was further improved over those used in earlier flights. For example, the micrometeorites were not only counted but classified as to their physical character, energy, and destructive power, and more accurate measurements were made of the composition and structure of the neutral atmosphere.

Specifically, the micrometeorite analyzer experiment was prepared in Hungary, the Soviet Union and Czechoslovakia; the electron concentration was measured by a German instrument; the positive ions and electron temperature by Bulgarian and Russian equipment; the mass spectrometers by Russian and Czech scientists; the mass spectrometer calibrator in Romania; the memory unit in Germany, and the Mayak radio transmitter in Czechoslovakia.

11. Interkosmos 13

Interkosmos 13 was launched March 27, 1975, to study dynamic processes in the magnetosphere and the polar ionosphere, carrying Soviet and Czechoslovak equipment. Coordinated ground observations were made by stations in Bulgaria, Hungary, the German Democratic Republic, the Soviet Union, and Czechoslovakia.

12. Interkosmos 14

Flags of nine socialist states were flying at Plesetsk when Interkosmos 14 was launched on December 11, 1975, with representatives of Bulgaria, Hungary, Czechoslovakia, and the U.S.S.R. present, since their experiments were being carried. The C–1 vehicle was used to place the payload in an orbit 1,707 by 345 kilometers at an inclination of 74 degrees, and with a period of 105.3 minutes.

The purpose of the flight was to continue research on low-frequency electromagnetic fluctuations in the magnetosphere, study the structure of the ionosphere, and measure micrometeoritic intensity.

On December 20 and 21, 1975, Perry and Dalberg picked up signals on 20.004 MHz from the Mayak ionosphere beacon transmitter. Failure to pick up further signals before the end of the year implies that this beacon operates "on command".

III. Other Recent Scientific Flights

A. THE PROGNOZ PROGRAM

1. Prognoz 1

While the Russians had gathered some solar data in a variety of flights, they had not operated in the most recent past complex multipurpose space laboratories doing such work. Current and comprehensive data are viewed as important not only to support the general advance of science, but to aid the weather reporting work by cloud cover picture-takers, and also to aid solar flare predictions when manned flights are planned.

Kosmos 159 looked as if it might be such a satellite when it was launched on May 17, 1967 into an orbit ranging between 60,600 and

380 kilometers at an inclination of 51.83 degrees. However, no findings have been noted in the literature and the flight was not repeated.

Prognoz 1 was launched on April 14, 1972 into an orbit ranging from 200,000 and 950 kilometers, using the A–2–e launch vehicle, and placed in an orbit inclined at 65 degrees with the launch occurring at Tyuratam. It was described as intended to study corpuscular, gamma, X-ray, and solar plasma interactions with the magnetosphere. The weight was given as 845 kilograms.

Later, pictures were released to show the probe as being a pressurized cylinder with hemispherical ends, 4 solar panels, and various external instruments and antennas. The payload was put in its highly elliptical orbit from an Earth orbiting platform, and then after separation from its probe rocket, it used special memory devices to orient itself toward the Sun and spin-stabilize it.

It carried an X-ray spectrometer and proportional counter in the 1,500 to 30,000 electron volt range, and scintillation spectrometer for gamma rays in the 30,000 to 350,000 electron volt range. Another spectrometer measured the proton flux in the 1 to 35 million electron volt range. It had a Cerenkov counter for electrons in the 40,000 to 140,000 electron volt range, and a scintillation spectrometer for protons in the 30,000 to 210,000 electron volt range. Other devices measured the solar wind, and radio emissions in the 1.6 to 8 kiloHertz range and also in the 100–700 kiloHertz range. It also had a magnetometer, orientation detectors, and dosimeters.

2. Prognoz 2

Prognoz 2 seems to have been virtually a repeat of the earlier flight. It was launched on June 29, 1972 into an orbit ranging from 200,000 kilometers to 550 kilometers at an inclination of 65 degrees. In addition to the experiments as listed for its predecessor, it also carried a French solar wind experiment.

3. Prognoz 3

This flight came on February 15, 1973. It carried about the same instrumentation as its predecessors. The orbit ranged from 200,000 to 590 kilometers, at an inclination of 65 degrees.

A followup report in early 1974 implied all three payloads were still active, but was not quite so specific as to state this. It said that the devices were calibrated periodically, and were returning data. A still later report on February 16, 1974, as Prognoz 3 began its second year, mentioned only Prognoz 3 as active. There had been 160 radio sessions with it to report data on solar activity and on solar-terrestrial relationships.

4. Prognoz 4

After a lapse, the Prognoz program was renewed with the launch of Prognoz 4 on December 22, 1975. It was described as being in general like its predecessors, except the weight was a little higher at 905 kilograms. It was designed to study the corpuscular and electromagnetic radiations of the Sun and magnetic fields near Earth. The orbit was 199,000 by 634 kilometers at a 65 degree inclination, with an orbital period of 95 hours, 40 minutes. It was launched by an A–2–e rocket system from an orbital launch platform.

B. FRENCH PAYLOADS CARRIED BY SOVIET LAUNCH VEHICLES

1. Oreol 1

On December 27, 1971, the Russians used a C–1 launch vehicle at Plesetsk to put into orbit a French payload, Oreol 1 (Aureole 1). The orbit, inclined at 74 degrees, ranged between 2,500 and 410 kilometers. This payload was part of a cooperative program called Arcade (Arkad). Its purpose was as a follow-on to the Soviet Bloc experiments with Kosmos 261 and 348, both of which made auroral and ionospheric studies. Although the payload was French, cooperating ground observatories were in Bulgaria, Hungary, the German Democratic Republic, Poland, Romania, Czechoslovakia, and the U.S.S.R.

Apparently some of the instrumentation was from the Space Research Institute of the Soviet Academy of Sciences to supplement what came from a French research center in Toulouse. It had been in preparation for three years. In general, the French experiments related to their special knowledge of low-energy ranges of electrons and protons, while the Soviet specialty has been those in the high energy range, so that the two complemented each other very well. The instruments measured the spectra of particles over a broad energy range, including the integral intensity of protons and the ion composition of the atmosphere.

The ship also carried an orientation system using a Sun-seeker, and a three-component magnetometer; a radio telemetry system, and a radio system for monitoring the orbital parameters and for sending commands from the ground.

2. MAS–1

MAS–1 was a small French pickaback which they called SRET–1 which rode to orbit on Molniya 1–20 from Plesetsk on April 4, 1972. The orbit was about the same as that of the Molniya—39,260 by 480 kilometers at an inclination of 65.6 degrees. The purpose of the French experiment was an engineering test of the characteristics under flight conditions of different kinds of solar cells. Later the weight was listed as 15 kilograms. Its shape was that of two pyramids, base to base.

3. Prognoz 2

The French part of Prognoz 2 was only supplemental instrumentation. This was designed to study the solar wind, outer regions of the magnetosphere, gamma rays of the Sun, and search for neutrons of solar origin. The flight occurred on June 29, 1972 from Tyuratam at an inclination of 65 degrees, and ranging between 200,000 and 550 kilometers.

4. Oreol 2

Oreol 2 was launched on December 26, 1973 at Plesetsk, using a C–1 vehicle. The orbit ranged from 1,995 to 407 kilometers at an inclination of 74 degrees. It carried essentially the same equipment as Oreol 1 of two years earlier. Its orbit permitted extensive probing of the regions where polar lights occur. The belief is that the upper layers of the atmosphere heat to a degree sufficient to initiate a controlled thermonuclear reaction, a temperature harder to achieve in a laboratory. Hence, the hope was that such studies would contribute toward the goal of initiating on Earth controlled thermonuclear reactions for power purposes.

As with the previous payload, there were coordinated ground observations made in various Soviet Bloc countries.

5. MAS–2

A second French pickaback was carried by Molniya 1–30, launched June 5, 1975. This was called MAS–2 by the Russians, SRET–2 by the French. The orbit ranged from 40,890 to 450 kilometers at an inclination of 63 degrees, after its launch from Plesetsk.

The payload was another engineering test, weighing 29.6 kilograms, about double that of its predecessor. It was to do research on the thermal protection of payloads in space conditions, to perfect equipment for a future weather satellite. The device had different radiation systems, and thermally insulated coatings of teflon, kenton, and other materials.

The French were not allowed to attend the launch of their payload.

6. Further French Experiments

In 1976, the Russians will launch a French satellite to study gamma rays and carry "Cytos", a biological experiment, and S–2, a solar energy test. In late 1975, a French experiment was carried on Kosmos 782, the biological satellite flight.[15]

C. INDIAN PAYLOAD CARRIED BY A SOVIET LAUNCH VEHICLE

1. Antecedents

Another chapter of this study discusses in detail the cooperative relationships between India and the Soviet Union in the field of space. India operates in its own territory in south India the Thumba international range, to date used only for sounding rockets and other short range flights. Indian airports have been used to a limited extent as refueling bases for Soviet long range aircraft which patrol the Indian Ocean area on potential air search missions connected with Soviet space flights. When Zond 5 was returned from the vicinity of the Moon, it was picked up in the Indian Ocean, and transported by ship to Bombay where it was transferred for air lift to the U.S.S.R.

Just as India has worked to broaden its capabilities in nuclear power, including thermonuclear research, and in nuclear explosives, it has also moved toward development of a comprehensive space program. It hopes in time to have its own launch vehicles as well as variety of scientific and applied mission satellites. To gain time and experience, it has been working with the Russians for Soviet support in launching its first pair of satellites. Later it hopes to have its own communications satellites, early warning weather satellites to give notice of potential natural disasters, and Earth resources satellites.

2. Aryabhata

The Soviet Union and India negotiated in August 1971 an agreement which was finally signed on May 10, 1972 by whose terms, a joint effort would be mounted to launch a satellite. India had some 200 specialists at work in Bangalore, of whom 50 eventually went to Kapustin Yar for the launch. The satellite was the heaviest first satellite of any nation yet to enter the field of space flight. It was announced on April 9, 1975 that the satellite had been shipped from India to the launch site, some months later than orginally planned.

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[15] Le Figaro, Paris, October 2, 1975, p. 13.

The launch of Ariabat (Aryabhata) came on April 19, 1975 at Kapustin Yar. It was put into an orbit ranging from 619 to 563 kilometers at an inclination of 50.7 degrees. The C–1 launch vehicle had been used. The payload weighed 360 kilograms. Tracking was done from the Soviet Union until the orbit was well established, and then thereafter was done both in the U.S.S.R. and in India. The name Aryabhata honored an Indian mathematician of antiquity.

The experiments covered the fields of X-ray astronomy, solar gamma and neutron radiation, and particle flows and radiation in the ionosphere. While most of the equipment had been built in India, the solar cells and memory units were Soviet. The third day after launch, the main control was passed from Moscow to Hyderabad. The principal tracking stations were at Bears Lake near Moscow and Sriharikota near Madras. The payload was spin-stabilized.

After five days of flight, 60 orbits, the payload was shut down because of power supply problems. Later these were resolved, and full operation began again. By June, it was reported it was still working well with 950 orbits completed. Other reports discount the return to full operations.

3. A Second Flight

The Delhi domestic radio announced on April 23, 1975 that a second space agreement had been signed between India and the U.S.S.R. On May 8, Prime Minister Indira Gandhi announced the second Indian satellite would be launched in 1977 or 1978 by the U.S.S.R. There was speculation it might be an Earth resources satellite.

By December 1975, the second Indian satellite was described as planned to have two TV cameras to return real-time pictures of a 325 kilometer square area at a time, plus radiometers to measure ocean surface temperatures and land humidity. It will be spin-stabilized.[16]

D. SWEDISH COOPERATIVE PROGRAMS

With little fanfare, Sweden has begun space cooperation with the Russians. Local Swedish newspapers quoted Swedish scientific sources as saying a Swedish experiment and a Czech experiment were lost in early June, 1975 in a failure at launch of a B–1 class vehicle at Kapustin Yar.[17]

A second Swedish payload is to be launched by the Soviet Union in 1976. Even more ambitious plans lie in the years following, according to private conversations with Swedish engineers.

E. SOVIET VERTICAL ROCKET PROBES

1. National Flights

The record of major Soviet vertical sounding rockets is incomplete, but even those that are known show they have made a significant contribution to the total program and to orbital flights which followed them. Most of the major sounding rockets have been launched at the Volgograd Station, otherwise known as Kapustin Yar. Smaller sounding rockets and weather rockets have been launched not only there but

[16] Flight International, London, December 11, 1975, p. 865.

[17] See also press release of the Swedish Space Corporation dated Jan. 22, 1976, describing the experiment and the failure.

at such places as Kheys (Hays) Island, on Soviet scientific research ships at sea, and even in Antarctica.

The largest sounding rocket the Russians have named is one they call the A–3, which in U.S. nomenclature is the SS–3, and which NATO calls the Shyster. It is possible that the major international cooperation flights use the Sandal or SS–4, that is, the first stage of the B–1. One mission was so far ahead of the rest in its reach that it is more likely it used the SS–5 Skean, that is, the first stage of the C–1.

In May 1957, the Russians announced they had sent a rocket 211 kilometers up, which carried five dogs. The payload weighed 2,196 kilograms.

On February 21, 1958, a very complex geophysical rocket with a wide range of atmospheric and solar experiments was sent 473 kilometers up. The payload weighed 1,515 kilograms.

On August 27, 1958 a payload of 1,690 kilograms was sent up to 452 kilometers, carrying two dogs, Belyanka and Pestraya.

On July 2, 1959, a rocket carrying about 2,000 kilograms of payload was sent 241 kilometers up. It carried dogs named Otvazhnaya and Snezhinka, and a rabbit named Marfusha.

On July 10, 1959, another rocket with a payload of about 2,200 kilograms was sent about 211 kilometers up, this time carrying several dogs including Otvazhnaya again.

On June 15, 1960, a rocket with a payload of 2,100 kilograms was sent 221 kilometers up. Included this time were a rabbit and two dogs, including Otvazhnaya on a fifth flight.

There were similar sounding rocket flights on June 6 and June 18, 1963. The first went 563 kilometers up.

On September 20 and October 1, 1965, rockets were sent about 480 to 500 kilometers up doing wide ranging geophysical experiments including taking various measurements of the ionosphere and photographs and spectrographs of the Sun in the ultraviolet and X-ray wavelengths.

By looking at the parameters of these flights, they were probably all conducted with use of the A–3 (SS–3 Shyster) geophysical rocket.

A new series of flights began in 1966, quite possibly with the same launch vehicle or perhaps its SS–4 Sandal successor, but adding to the usual range of geophysical experiments some unusual propulsion experiments as well. The first was called Yantar 1, launched on October 13, 1966. It made studies of electron concentrations and photo emissions in the ionosphere. But it also scooped up atmospheric nitrogen, after attaining speed through its rocket motor, to sustain a special ion electrical rocket with propellant. This was seen as leading toward future hypersonic aircraft. In 1969 there were more Yantar flights, but the dates and the performance have not been reported in detail. All the flights seem to have operated in the altitude range of 100 to 400 kilometers.

On October 12, 1967, a single, much more ambitious sounding rocket flight was made, and it seems likely that a larger launch vehicle had to be used, such as the first stage of the C–1 (SS–5, Skean). Pictures released of the payload showed an instrument container much like a small Kosmos satellite. If the larger rocket was used, it probably went from Tyuratam, as no pad had been used at Kapustin Yar by that year for such a larger vehicle.

The payload was designed to make a variety of solar and ionospheric measurements, including measures of the concentration and location of electrons and positive ions. The flight lasted 52 minutes, during which time it reached an altitude of about 4,400 kilometers. The payload was separated from the rocket body by more than 100 kilometers to minimize distortion of data which might occur in a location close to the carrier rocket.

In 1970 there were additional geophysical rocket launchings. One of these came on October 3, and flew up to about 500 kilometers. It did solar ultraviolet and X-ray studies.

On September 24, 1971, a geophysical rocket was sent to an altitude of 230 kilometers. A similar rocket was launched on October 9, 1971 to an altitude of about 500 kilometers.

2. The Vertikal International Program

The Interkosmos organization of Soviet Bloc countries has sponsored geophysical sounding rocket flights under the name Vertikal. Vertikal 1 was launched on November 28, 1970 at Kapustin Yar, probably using the first stage of the B–1 (SS–4 Sandal), but possibly still using the SS–3 Shyster, or Soviet designated A–3. The payload was sent about 500 kilometers up. It weighed 1,300 kilograms. The rocket was 23 meters long with a diameter of 1.66 meters. Instrumentation measured the X-ray spectrum, and the concentration of electrons and positive ions, as well as electron temperature. These instruments had been manufactured jointly by the German Democratic Republic and the Soviet Union to specifications also supplied by Bulgaria and Czechoslovakia.

On August 20, 1971, Vertikal 2 was launched and it flew to an altitude of 463 kilometers. The description of payload weight, dimensions, and participants seemed to match those of the earlier flight. The payload section separated from the single stage carrier rocket at about 90 kilometers, carried by momentum to the high point of the flight. Parachute recovery was used to retrieve the payload.

On September 2, 1975, Vertikal 3 was launched at Kapustin Yar, at 0740 Moscow time, presumably with the same B–1 first stage or Soviet designated A–3 sounding rocket. It reached a maximum altitude of 502 kilometers, following separation from the single stage carrier rocket at 97 kilometers altitude. The experiments continued the previous work on interactions between solar shortwave radiation and the ionosphere and upper atmosphere. The assembly and launch itself were conducted by representatives of Bulgaria, Czechoslovakia, the German Democratic Republic, and U.S.S.R. Two weather rockets with Bulgarian and Soviet equipment were launched at the same time, and various ground stations made measurements at the same period.

It was interesting that during the summer of 1975, the Russians put on display in the usual Moscow museum a replica of the Vertikal payload, but referred to the payload as a Prognoz, the name reserved for the three flights which had ranged out in very eccentric Earth orbits. This replica or one like it was at the Paris Air Show in the spring of the same year.

IV. The Second Generation of Planetary Flights

A. SOVIET USE OF PLANETARY WINDOWS

Despite its many failures along the way, the Soviet commitment of hardware to exploration of both Venus and Mars has been impressive. The brief table which follows summarizes by launch opportunity what use the Rusians made of these:

Mars

1960—2 failures
1962—2 failures, Mars 1
1964—Zond 2 (Zond 3, delayed)
1967—None
1969—Rumored failures
1971—Kosmos 419, Mars 2, Mars 3
1973—Mars 4, Mars 5, Mars 6, Mars 7
1975—None

Venus

1961—Tyazheliy Sputnik 4, Venera 1
1962—3 failures
1964—(Kosmos 21 test) Kosmos 27, Zond 1
1965—Kosmos 96, Venera 2, Venera 3
1967—Kosmos 167, Venera 4
1969—Venera 5, Venera 6
1970—Kosmos 359, Venera 7
1972—Kosmos 482, Venera 8
1973—None
1975—Venera 9, Venera 10

The programs to both planets at first used the A–2–e launch vehicle with multiple launch attempts at every opportunity from 1960 on. Then a Mars oportunity was skipped in 1967, to be followed by predictions of Soviet scientists that the 1969 opportunity would see an expanded and improved effort to Mars. There followed rumors in 1969 that there were launch attempts which failed. When flights resumed in 1971 and thereafter, the launch vehicles had been upgraded to the D–1–e size. The corresponding skipping of a Venus opportunity came in 1973, and predictions were borne out when the resumption of the program in 1975 also reflected an upgrading of the effort to use of the D–1–e larger launch vehicles. But even this vehicle was not equal to carrying such payloads to Mars during the 1975 opportunity and no Mars flights occurred on the Soviet side.

An earlier section of this chapter reviewed all the A–2–e flights. This section reviews what is known about the second generation flights using the D–1–e.

B. THE MARS ATTEMPTS OF 1971

Although the rumors of the summer of 1968 were that there would be new major Mars attempts late in 1969, there were no successful launches announced and no Kosmos hidden failures in Earth orbit at appropriate windows.[18] However, there were multiple rumors of launch failures at the appropriate window. The 1971 opportunity was taken by both the Soviet Union and the United States.

1. Launch Failures

The United States was unsuccessful on May 8, 1971 in sending Mariner 8 on its way to Mars. The Centaur stage went out of control and the payload fell in the Atlantic near Puerto Rico.

[18] Flight International, London, March 27, 1971, p. 793.

Less publicized was the Soviet launch of Kosmos 419 on May 10, two days later. Although the Russians named the launch, they did not add the usual statements about everything going well. It attained Earth orbit, but did not fire its Zond rocket which would have launched it toward Mars and given it a Mars name. By inference, it almost certainly was like the flights which followed shortly in being launched by a D–1–e. Within two days it had decayed from orbit.

2. Launch of Mars 2, Mars 3, and Mariner 9

Moscow announced the successful launch of Mars 2 on May 19 as soon as it was clear that its Zond rocket had launched it on a trajectory toward Mars from its orbital launch platform. It was announced as weighing 4,650 kilograms, not including the weight of the accompanying rocket stage. This was a D–1–e launch. Telemetry was being received on 928.4 MHz.

The same kind of announcement came on May 28 that Mars 3 was also on the way to Mars in a virtually identical pattern, and with the same weight, except that Mars 3 also carried a French Stereo experiment designed to supply readings of solar radio emissions and cosmic rays in the interplanetary medium as part of synoptic measurements to be made in France and in the Soviet Union.

Mariner 9 was successfully launched on May 30, preceded by the usual U.S. detailed explanation of its intended purposes and instrumentation. Also as usual corresponding details on the two Soviet craft were missing at that time, only to be revealed much later.

3. In-flight Progress

The Soviet releases of news presently were expanded to report both their flights would be measuring data from the interplanetary medium, although only Mars 3 carried the French experiment. The Russians said the directional antennas on the two craft would greatly increase the flow of data over that of earlier experiments.

On June 8, a course correction was made by Mars 3 to bring it more nearly to its intended trajectory. A similar course correction was carried out by Mars 2 on June 17.

By July 27, it was announced there had been 43 communications sessions with the craft, with continuing measurements of solar corpuscular radiation and of galactic cosmic rays.

On August 21, a similar announcement also added that each craft carried 8 separate spectrometers to determine the speed, temperature, and composition of the basic components of the solar wind over time, in the range of energies from 30 to 10,000 electron volts. This was the last known public reference to the flights for many months, and some Western observers began to suggest the flights had failed.[19]

As had been done with the flghts from Venera 4 on, each Mars craft had its analog operating in a vacuum chamber on Earth to receive the precise commands being sent to the real craft, providing an opportunity to see how they responded, and also to aid in the solution of problems which might arise. For the real craft at the distances involved, the signal to fire a rocket and to receive confirmation back took longer than the firing itself.

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[19] Flight International, London, Oct. 7, 1971, p. 592.

4. Mars 2 Arrival

The Russians waited until November 30 to announce that on November 27, 1971, Mars 2 had entered on orbit around Mars, with an apoapsis of 25,000 kilometers, a periapsis of 1,380 kilometers, an orbit inclination of 48°54′ to the Mars equator, and a period of 18 hours. As the payload first approached the planet, a capsule was separated from the main bus, and was delivered to the surface of the planet at 45°S., 58°E. It carried a pennant bearing the coat-of-arms of the Soviet Union. The main bus was to continue a study of the planet from orbit. There had been further course corrections on November 20 and 27.

5. Mars 3 Arrival

Not until December 7 did the Russians announce that Mars 3 had reached the planet in similar fashion, on December 2, 1971. This time the lander was referred to as a descent craft which parachuted to land at 45°S., 158°W. after which it transmitted signals to Earth. Both Mars 2 and 3 were described as opening the way to conducting a search for life, but were not themselves equipped for this purpose. The Mars 3 lander also carried Soviet insignia to the surface. The Mars 3 bus was put into a more eccentric orbit with a low point 1,500 kilometers above the surface, and an 11-day period of orbit. Presumably the inclination was similar to that of Mars 2, and the high point should have been about 190,700 kilometers. Signals from the surface were transmitted by a weak omnidirectional system to the orbiting bus where they were recorded and later played at a slower data rate via the high gain antenna pointed toward Earth. Braking of the lander was accomplished by aerodynamic ballistic entry, and after a marked slowing of the craft, a drogue chute was released, followed by the main parachute. A rocket braking system supplied the final reduction in velocity to permit a survivable landing. This brake was activated by a radio altimeter 20–30 meters above the surface. It was stated that the signals from the surface had been brief, and were replayed from the Mars 3 bus over the period December 2 to 5.

The landing site of the Mars 3 vehicle was in a relatively featureless rounded hollow about 1,500 kilometers across. Orbital television cameras with a resolution of 0.3 kilometers could detect no craters, even though beyond a surrounding area of ridges and cliffs, there were numerous craters.

On December 18 it was further reported when the Mars 3 lander reached the surface and was stabilized, that after a lapse of 90 seconds, the several instruments and television system were activated. The TV began to take a panoramic view, but after 20 seconds of transmission, all signals from the lander ceased. The small portion of picture, when retransmitted to Earth, revealed no noticeable contrast or details.

Obviously, the lander portions of the two flights must have been a disappointment to the Russians. They were probably mechanically similar. Mars 2 failed to survive its landing, and Mars 3 ceased to function very shortly thereafter, when it might have been expected to operate for some hours or days before its batteries ran down. The cause of the failure is unknown.

Aviation Week on March 6, 1972 reported that the real problem was a failure in the relay antenna on the Mars 3 bus which malfunctioned,

while the lander probably continued to transmit data and pictures from the surface, which could not be relayed to Earth. Most observers today do not consider this the most likely explanation, and suggest rather that dust storm conditions on the surface overwhelmed the lander.

6. Instruments on the Landers

The December 18 Soviet account of Mars 3 probably applied to both landers. Mars 3 carried atmospheric temperature and pressure sensors, a mass spectrometer to determine atmospheric components, a wind velocity meter, devices to measure the chemical and mechanical properties of the soil, and a television system to supply panoramic views of the surroundings. The lander has not been pictured deployed, except possibly on a 1972 postage stamp, but probably was an outgrowth of the self-righting petal design used for Luna 9 and Luna 13. The landed weight (not revealed at the time) was 635 kilograms.[20]

7. The Orbital Buses and Their Activity

The Russians announced on December 15, 1971 that both Mars 2 and 3 had taken photographs of the planet at different distances and the pictures had been transmitted to Earth by facsimile after development in an automatic on-board laboratory. On December 18, further details supplied described the camera system as including both a wide angle lens and a 4° narrow angle lens, and there were different light filters as well which could be shifted over the lenses on command. The continuing dust storm on Mars which hampered the much more ambitious picture taking by Mariner 9 plagued the Russians as well.

Another Soviet announcement said the French Stereo experiment carried by Mars 3 used a data compression system reducing by 100-fold the burden of transmitting significant results to Earth.

Pravda carried a more complete account of the bus instrumentation in December 19 for both Mars 2 and 3:

An infrared radiometer to construct a Mars surface temperature distribution chart (8–40 microns).

An instrument to determine water vapor concentrations by spectral analysis of absorption in the 1.38 micron line.

An instrument to study surface relief by measuring the amount of carbon dioxide along a sighting line, according to the intensity of the 2.06 micron absorption band (an infrared spectrometer).

An instrument to study the reflectivity of the surface and atmosphere in the visible spectrum of 0.3 to 0.6 centimeter range, and for determining the dielectric permeability of the surface and temperature to a depth of 35–50 centimeters.

An instrument to determine the density of the upper atmosphere and the concentration of atomic oxygen, hydrogen, and argon—an ultraviolet photometer.

Two television cameras on the same axis, one wide angle, and the other narrow angle. (It was not clear how the television description squared with the alternate Soviet report of photographic film being developed on board for facsimile transmission to Earth.)

In general, the two buses seem to have performed about as planned. On December 27, 1971, the Russians announced the discovery of atomic

[20] Oja, Heikki, in Spaceflight, London, July 1975, p. 279, quoting a Soviet scientist.

hydrogen and atomic oxygen in the upper atmosphere of Mars. By January 9, 1972, they said work was proceeding in orderly fashion, and that the dust storm seemed to be subsiding. Pictures taken with the red filter were showing dark areas of "seas" again, while ultraviolet pictures again showed bright clouds. A routine progress report was issued on January 29.

TASS further reported on March 1, 1972 that the dust storm was over. The soil temperature on Mars at a depth of several tens of centimeters was found to be largely independent of the time of day. The ionosphere was defined as beginning at a height of about 80–110 kilometers, with electron concentrations sharply increasing, then gradually diminishing with height. The orbital buses were said to be continuing to explore the structure and surface of Mars, taking pictures of the planet, and measuring the temperature, pressure, density, and chemical composition of its atmosphere. A second bulletin that day said that by March 1, Mars 2 had made 127 orbits of the planet, and Mars 3 had made 7 orbits around Mars. It concluded saying, "The program for the work of stations Mars 2 and Mars 3 which are orbiting Mars as its artificial satellites is nearing completion.[21] This was attributed to the growing distance of Mars from Earth.

Only over a period of time as analysis proceeded did more of the findings become available. On March 22, 1972, it was reported that photography had played a minor role compared with the other data gathered. Mars 3 did three surveys of the planet during the dust storm and four more afterwards. The estimate was that billions of tons of material had been on the move during the dust storm. Water vapor was found to be about 1/2,000 that of the Earth, with a measurement in the range of from 50 to under 10 microns.

In April it was revealed the camera systems used had a 52mm focal length for the wide angle camera and an unspecified longer length for the narrow angle. Color filters were red, green, and blue. Some 12 frames were exposed and automatically developed on board, then scanned with 1000 lines of 1000 elements each, for transmission to Earth where they were recorded both on magnetic tape and on electrochemical paper.

Although the main work program ended in March, the two orbiters were still being contacted in July at a distance of 385 million kilometers.

The program was reported formally completed by August 22, 1972. By then Mars 2 had completed 362 orbits and Mars 3, 20 orbits of the planet. They had returned interplanetary data, and done integrated studies of the surface and atmosphere of Mars in visible, IR, and UV ranges, plus radio studies. They measured thermal differences by region and variations in altitudes. The estimate on water vapor was lowered to 1/5,000 that of Earth. The UV studies revealed the structure, height, composition, and temperature of the upper atmosphere. The radio studies gave the pressure and temperature at the surface. Dust particle size and concentration was measured. The magnetic field was measured.

The temperature range was found to be between 13° C. and −93° C., except at the north pole where it was −110° C. The temperature drops

[21] TASS, March 1, 1972, 1446 GMT

quickly with darkness. There was about a 10° difference between seas and continents with the seas being warmer. Mountains up to 3 kilometers high were found, and depressions ran to a depth of 1 kilometer. The maximum water vapor reading was 5 microns (1/2,000 of Earth). The air was mostly carbon dioxide, but at high altitudes, separated into carbon monoxide and atomic oxygen, while water also broke into atomic hydrogen and atomic oxygen. The temperature rose with altitude. The ionosphere was about one tenth as dense as that of Earth, with its maximum strength at 140 kilometers. The magnetic field was about 8 times as strong as in the interplanetary medium. Air glow showed in photographs of the terminator.

C. THE MARS ATTEMPTS OF 1973

The year 1973 was more difficult than 1971 in terms of the energy requirements for sending payloads to Mars. Consequently, when the Soviet flights came, they fell into a different pattern. There were two pairs of flights, each made up of an orbiter and a lander, with ability to switch communications between members of pairs in order to increase redundancy. Launching a total of four D–1–e vehicles represented a very considerable Soviet investment.

1. The Launches of Mars 4, Mars 5, Mars 6, and Mars 7

Mars 4 was launched on July 21, 1973 at 2231 Moscow time. Soviet observatories were able to make optical observations as the payload sped toward Mars after departure from an Earth orbiting platform. Soviet accounts spoke of the elaborate controls at the launch center with monitoring television screens and reference data available at the touch of a button. In the Atlantic were three ships to monitor the escape from the platform. These were the *Akademik Sergey Korolev*, the *Bezhitsa*, and the *Ristna*. Molniya was used as a link to the U.S.S.R.

Mars 5 was launched on July 25, 1973 at 2156 Moscow time, and it departed from its Earth orbital platform at 2315 Moscow time. It was described as being like Mars 4, intended to study Mars and its surrounding space.

Mars 6 was launched August 5 at 2046 Moscow time. It was described as different from the two earlier flights, and intended to work primarily with Mars 4. It was also said to carry French experiments for solar studies. This time the three ocean tracking ships named before also had the *Morzhovets* in the Atlantic to help out. Soviet observatories extended their reach to make optical searches for Mars 6. The Crimean observatory found the payload at distances up to 465,000 kilometers from Earth, and the carrier probe rocket was located first at 435,000 kilometers.

Mars 7 was launched on August 9, 2000 Moscow time, being put into an intermediate Earth orbit, and then sent on its way. It was to work closely with Mars 5, and Mars 7 was like Mars 6 in carrying French solar study equipment. The Alma Ata observatory was reported to be doing optical tracking of both Mars 7 and its carrier rocket.

2. The Flight En Route.

Midcourse corrections were made to Mars 4 on July 30 and to Mars 5 on August 3. This time the French experiment for solar studies en

route was called Zhemo. This was for study of the distribution and intensity of fluxes of solar protons and electrons. Other French equipment of the Stereo type was for making solar radio emission studies. Course corrections were applied to Mars 6 on August 13 and to Mars 7 on August 16. Though still generalized, a more complete description than usual of the mission of the four craft was issued on September 22, relating to the studies to be done both from orbit and on the surface of the planet, including studies of the physical characteristics of the surface rock, and surrounding terrain including use of photography, and also studies of the atmosphere. As the voyages continued, update reports were issued about monthly.

3. Arrival at Mars

Mars 4 reached Mars on February 10, 1974. The retrorocket failed to fire, so it did not enter orbit around the planet, instead making a close pass at 2,200 kilometers. It was able to take photographs for development on board and transmission to Earth by facsimile scan. The payload continued to gather interplanetary data thereafter.

Mars 5 reached Mars on February 12 at 1845 Moscow time, firing its retrorockets to be placed in an orbit around Mars with an apoapsis of 32,500 kilometers and a periapsis of 1,760 kilometers. The orbit was inclined at 35 degrees to the Martian equator, and had a period of 25 hours. All of these steps were accomplished by an on-board autonomous navigation system.

Mars 6 reached the vicinity of Mars on March 12, 1974. While its bus continued in heliocentric orbit, it separated a descent module which used aerodynamic braking in the atmosphere and then a parachute system to reach the surface of the planet. It landed at 24° S., 25° W.

Mars 7 reached the vicinity of Mars three days earlier on March 9. Its bus also continued in heliocentric orbit. Its descent module separated as planned, but a malfunction of an onboard system made it miss the planet by 1,300 kilometers.

4. Follow-up Details of the Flights

Even the first announcement noted that the probes through use of a wide range of observed wavelengths had been able to answer questions on Mars relief, temperature, heat conductivity, soil structure and composition, chemical composition of the lower atmosphere, and structure of the upper atmosphere. More water vapor was found in some places this time than had been the case two years earlier.

It was then disclosed that contact with Mars 6 had ceased 148 seconds after the parachute had opened, in the immediate proximity of the surface. All data up to that point were relayed from the landing module to the bus for further relay later to Earth. Dried river beds were detected.

Soviet papers carried followup articles by leading Soviet scientists who were drawing conclusions from the most recent flights, almost as if to fill the gap in real information, as it was too early for new data to be fully interpreted. R. M. Sagdayev, Director of the Institute of Space Research, said that Mars was more Earth-like than had been supposed, and he spoke of its being geologically active at least in the past and possibly having had water at some stages. He gave a refined figure for the orbital period of Mars 5 as 24 hours, 53 minutes. He

explained that Soviet measurements of thickness of atmospheric strata were revealing differences in ground elevation which were not apparent from photographs. He noted that the IR data and daily changes told about soil thermal conductivity and hence structure. Study of the surface in visible and near-IR wavelengths as to brightness and polarization could answer questions of soil composition. The gamma spectrometer readings revealed the nature of rocks. The photometer gave localized readings as high as 60 microns for water traces in the atmosphere, several times what had been read by Mars 3, and giving a 5-fold range among tested localities on this flight. He said the UV photometer revealed some ozone traces. He reported the outer atmosphere as atomic hydrogen at 1,216 angstroms. The magnetic field is 30 gammas near the planet, helping to divert away the solar wind.

He said that Mars 4 and 5 both took pictures of Mars at resolutions ranging from 1 kilometer down to 100 meters, from a distance of about 2,000 kilometers. Through the use of the adjustable filters, color pictures had been created. In the southern hemisphere, several strips 1,000 kilometers long had been taken. He also said that the Mars 6 lander had been separated at a distance of 48,000 kilometers from the planet, and the bus had passed the planet at 1,600 kilometers. Aerodynamic braking had lasted 5 minutes. Pressure at the landing site had been 6 millibars, about 1/100 the level of Earth.[22]

What was especially significant is that Mars 6 managed to send back from its lander the first direct readings of pressure, temperature, and chemical composition of the atmosphere.

The Russians finally published color photographs of Mars taken by Mars 4 and 5. They revealed that the plains are orange, the mountains blue, and the craters bluish-green. Mountains may range up to 8 or even 11 kilometers high with gentle slopes [23] Later U.S. scientists criticized the pictures as lacking adequate calibration for scientific purposes.[24]

The first complete review of findings was published in January and February 1975, with a whole issue of the journal devoted to the four payloads.[25]

Apparently the landers for Mars 6 and 7 were 635 kilograms each.[26]

Other summary findings were carried in the COSPAR report on 1974 activities.[27] The findings were consistent with the earlier brief reports, but gave greater details. Mars 6 had hit at atmosphere at a speed of 5.6 kilometers per second at 12:05:53 Moscow time. Air drag slowed the speed to 600 meters per second by 12:08:32, when the parachute opened. It reached the surface at 12:11:05, and the radio signals ceased at that moment. This meant it had taken 2 minutes, 39 seconds to slow in ballistic flight, and 2 minutes, 33 seconds more for the parachute to bring it to the surface.

The mass spectrometer was not set to function until after touchdown, so did not return data. Other sensors during the flight down to the surface disclosed that 35±10 percent of the atmosphere was an inert

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[22] Pravda, Moscow, March 17, 1974, p. 3.
[23] TASS November 11, 1974, 0912, citing Zemlya i Vselennaya.
[24] Aviation Week, New York, February 10, 1975, p. 11.
[25] Komicheskiye Issledovaniya, Moscow. Vol. XIII, No. 1 (Not available to this study).
[26] Oja, Heikki, in Spaceflight, London, July 1975, p. 279.
[27] Space Research Conducted in the U.S.S.R. in 1974, COSPAR Report, 18th Plenary Session. Translated into English and republished as JPRS 65778, September 29, 1975 by the Joint Publications Research Service. pp. 2–21.

gas, perhaps argon. At the landing site, the air pressure was measured as being 6 millibars, and the temperature 230° K. (−3° C.).

Meanwhile the orbiting vehicle, Mars 5, was returning a wide variety of other data. It made a radio probe of the atmosphere at 8–32 cm. It used a radio telescope at 3.5 cm. Its infrared radiometer worked in the 8–26 μm range. The spectrometer with an interference filter worked in the 2–5 μm range. A narrow band photometer with interference filter studied the CO_2 band at 2 μm. Another narrow band photometer with interference filter studied the H_2O band at 1.38 μm. There was a photo-television complex of instruments to take pictures, develop the film, and scan these for facsimile transmission to Earth. Another photometer with interference filter covered the 0.3–0.8 μm range. Two polarimeters covered 9 narrow bands in the range of 0.35–0.8 μm. Another photometer studied the ozone band at 2,600 angstroms. A different photometer measured the intensity of scattered solar light in the Lyman alpha range of 1,215 angstroms. There was also a gamma photometer.

Several experiments were duplicated among the four main vehicles. Magnetometers were carried on Mars 4 and 7, as were plasma traps. Multichannel electrostatic instruments were carried by Mars 4 and 5. Mars 6 and 7 carried micrometeorite sensors and cosmic ray sensors. It was Mars 7 that also carried a French solar radio wave experiment.

Mars 5 made a study of the chemical composition of the atmosphere measuring the amount of water vapor and ozone. Mars 3, after the dust storm two years earlier had found only 10–20 μm of water vapor. But Mars 5 found some readings of up to 80 μm of water vapor, with variations of 2 to 3 fold even within short distances of a few hundred kilometers. Mars 5 found that the amount of ozone by volume was 10^{-5} percent, with the layer at 30 kilometers.

Between them, Mars 4 and 5 took 60 photographs, often of high quality. Those with resolutions as good as 1 kilometer were taken with a camera whose focal length was 52 mm. Other pictures with a resolution ranging up to 100 meters were taken with a camera with a focal length of 350 mm. Pictures scanned for return to Earth were done so either at 1,000 by 1,000 fineness or at 2,000 by 2,000 fineness. Mars 4 used a red filter. Mars 5 used a blue filter.

Apparently, not only was there the photo-television system, but also an optico-mechanical TV scanning system. In addition to the general filters referenced above, Mars 5 used other red, blue, and green filters, and a special orange light filter. From the pictures taken, rectified maps were produced which provided control points and links with the pictures taken two years earlier by Mariner 9. In one region it was possible to do a geomorphological study.

In summary, although the payloads collectively did much less than hoped of them, the mission was not the total loss some Western publications seem to have assumed. Further details are carried in the referenced Soviet reports.

A small amount of supplementary detail was carried in another Soviet publication. The Mars 4 and 5 photo TV systems were described as designed to attain 700 and 100 meter resolutions at best for survey purposes. The camera already described as having a focal length of 52 mm was called Vega. It was f/2.8, providing a 23 by 22.5 mm frame and its look angle was 35°42′. The other camera already described as

having a focal length of 350 mm was called Zufar. It was f/4.5, again with a 23 by 22.5 mm frame, and its look angle was 5°40′.[28]

D. THE VENUS ATTEMPTS OF 1975

1. Launch of Venera 9 and Venera 10

As expected, the Russians upgraded their Venus exploration effort by the use of the D–1–e class vehicle for the first time in launching Venera 9 on June 8, 1975. It was described as a new type of Venus spacecraft. Using the standard Earth orbital platform approach, the probe was sent toward Venus, with the announced purposes of studying Venus and surrounding space, and for doing studies of the interplanetary medium on the way. Radio Moscow added that the launch vehicle was larger than the one used for Soyuz (the A–2). Ships were placed in the Gulf of Guinea, the Mediterranean, and the Pacific to support the launch, with the Molniya 1 used for relay purposes. The flight was controlled from the Deep Space Communications Center at Yevpatoriya.

On June 14, Venera 10 was launched, and it was announced as similar in design and mission to Venera 9. It was launched in the same manner to put it on its trajectory.

2. En Route to Venus

TASS announced on August 8 that the flights were going well, and that Venera 9 would reach Venus on October 22, while Venera 10 would arrive there on October 25. Soviet sources noted that while earlier Venera probes had required many commands from Earth to control their course, this time there were on-board digital computers which made many of the necessary calculations, adding flexibility to the operations. Orbital corrections were made on June 21 and October 18, and there were 90 communications sessions, for Venera 9. Presumably the handling of Venera 10 was similar.

3. Landing of Venera 9

On October 20, Venera 9 was divided into separate lander and orbiter craft. On October 22 at 0658 Moscow time, the lander entered the atmosphere of Venus at a speed of 10.7 km/sec. It was protected within a two-hemisphere shell, and was able to withstand temperatures up to 2,000° C. (20,000° C.?) and 300 tons pressure. It used aerodynamic braking until it had slowed to 250 meters/sec. Then it cast loose one hemisphere and in succession used three parachutes. On the way down, it studied the cloud layers in detail. At 50 kilometers altitude it cut loose the main parachute, and relied on a disc-shaped aerodynamic brake for the rest of the descent, impacting at 6–8 meters/sec. The landing came at 0813 Moscow time. To cushion the impact, there was a compressible "doughnut" metal ring at the base of the lander, separated by struts, and this exhausted air under impact. Because the lander instrumentation had been precooled to minus 10° C. and its exterior equipment to minus 100° C. before entry, it was able to survive in functioning condition for 53 minutes on the surface. A special system of circulating fluids distributed the heat load. The lander carried a metal pennant with the Soviet coat-of-arms. It stood

[28] Tekhnika Kinoi Televideniya, Moscow. No. 9, 174, pp. 55–60.

approximately 2 meters high, and was equipped with flood lights to take a surface picture.

Preliminary findings suggested that the clouds through which it passed were 30 to 40 kilometers thick, with a base 30 to 35 kilometers high. The upper layers may have contained hydrogen chloride and hydrogen fluoride, while farther down there may have been bromine and iodine. The surface pressure was about 90 Earth atmospheres and the temperature 485° C.

The real surprise was to find that the lighting was as bright as Moscow on a cloudy June day, so that the floodlights were not required. Some 15 minutes after landing, a television panoramic picture began to emerge on Earth. There was no noticeable dust, and the picture was quite clear even without further processing. Details were good out to 50–100 meters. There was a scattering of rocks 30–40 cm across, and a large stone on the apparent horizon. The panorama generally reached out to 160 meters, and the horizon may have been 200–300 meters away, but this was in doubt and probably an understatement. There was a defined curvature between surface and air at this horizon. The fact that rocks cast shadows suggested that direct sunlight was reaching the surface, in contrast to the expected solid cloud cover. Surprisingly, also, the rocks were not eroded, but showed sharp cleavages as if relatively young.

Because the landing occurred on the sunlit side away from Earth, the data had to be relayed from the surface to the orbiter for further relay to Earth. With the Sun close to the zenith, it was believed the light was probably 20 to 25 times as intense as during the Venera 8 mission where the Sun was only 4.5° above the horizon.

4. Landing of Venera 10

On October 23, Venera 10 was divided into separate lander and orbiter. The lander arrived on October 25. It approached its landing site at a 20° angle. The temperature rose to 12,000° C. and the dynamic pressure reached 168 G's during aerodynamic braking. At 60 kilometers, the parachutes opened, and then we were dropped at about 49 kilometers. At 42 kilometers, the pressure was 3.3 Earth atmospheres and the temperature was 158° C. At 15 kilometers, the pressure was 37 Earth atmospheres, and the temperature was 363° C. Some 75 minutes after entry began, the landing came at 0817 Moscow time. After this the lander operated 65 minutes on the surface. It had also been precooled inside to minus 10° C., and its interior temperature at landing was 23° C., and its pressure was 2 Earth atmospheres. The surface pressure was 92 atmospheres and the temperature was 465° C. The wind was 3.5 meters/sec. The landing occurred about 2,200 kilometers away from the Venera 9 lander.

As with its twin, Venera 10 was successful in sending back a panoramic view of its surroundings. Picture transmission was over by 0922 Moscow time, and was relayed via the accompanying orbiter craft. This time the view showed large pancake rocks, possibly with cooled lava or other weathered rocks in between. At the control center, the telephotometer picture emerged from the receiving machine on paper tape, with breaks every so often to permit other data to be received. It took about an hour for the picture to be received.

The estimate was that Venera 9 had landed in alpine-type country about 2,500 meters elevation, while Venera 10 had landed in lower plains.

5. The Venera 9 and 10 Orbiters

Both orbiters were put into their respective orbits the same day as their landers went to the surface of Venus. As indicated above, each served as a relay station for data from the respective lander. Each carried a metal pennant with a bas-relief of Lenin.

The Venera 9 orbiter was estimated to be in an orbit with a high point of 112,000 kilometers and a closest approach of 1,300 kilometers, with the orbital period 48 hours, 18 minutes.

The Venera 10 orbiter was estimated to have a high point of 114,000 kilometers and a closest approach of 1,400 kilometers, with its period 49 hours, 23 minutes.

The mission of the orbiters is to explore the cloud layers of the planet, their structure, temperature, and radiation, using spectrometers, radiometers, and photopolarimeters. By using radio sounding, they were measuring the density of ions and electrons, and at high altitudes the energy spectra directly with ion traps. They were also measuring weak magnetic fields and particles in the solar wind stream.

Pictures taken in the UV range showed dark areas of equatorial circulation, like Mariner 10. Data are taped for later replay to Earth. The most recent reference was published November 21, when Venera 9 had made 15 revolutions and been contacted 40 times. Venera 10 had made 13 revolutions and been contacted 35 times. It was then revealed that France had supplied the UV spectrometers in use. Other equipment was used to measure the ratio of hydrogen to deuterium in the upper atmosphere.

V. The Third Generation of Lunar Flights

The first generation of lunar flights used the A–1 class of vehicle for direct injection into flight toward the Moon. This permitted the sending of about 400 kilograms and limited the variety of missions which could be performed. As explained earlier in this study, the fairly northern location of Tyuratam also limited the Soviet capacity to fly many space missions by the direct injection technique. So they shifted to the more powerful upper stage and to the orbital launch platform technique so that the escape path could be initiated near or over Africa.

This second generation system using the A–2–e raised the capacity of the basic rocket to send as much as 1,600 kilograms to the vicinity of the Moon. Within the limits of this newer basic craft, the Russians were able to accomplish a number of scientific and engineering "firsts". They had already been the first to fly by the Moon, to strike the Moon, to take photographs of the far side. Now they added the first survivable camera landed on the surface, the first orbit of the Moon, and the first pictures from orbit. The first generation flights had included Luna 1 through 3; the second generation were those of Luna 4 through 14, plus some unacknowledged partial failures in Earth orbit.

The weights carried by the second generation were still too small to carry out additional automated missions the Russians had in mind. The creation of the Proton or D class of vehicle with added upper stages provided the opportunity to do more. The new D–1–e class of

launch vehicle was first committed to a program to send men around the Moon. These Zond flights, numbered 4 through 8 before the program was abandoned, are treated in a separate chapter.

A. LUNA 15

As the summer of 1969 approached, the Americans had already had their previous Christmas flight of Apollo 8 to lunar orbit, and in the spring had practiced rendezvous operations in lunar orbit with Apollo 10. The Soviet Union had its full crop of rumors, confident predictions, and contradictory accounts about what the Russians were going to do to offset or even beat the upcoming Apollo 11 flight to the Moon with the goal of landing men for the first time. These rumors and their possible validity are treated in a different chapter.

By late June or early July there were rumors in Moscow that the Russians were about to do something spectacular within a few days related to the Moon. Several accounts tied these rumors to the big G–1–e vehicle in the Saturn V class. Rumors say it was launched, but failed to reach orbit. It is known that tracking ships which had been on station in various oceans including the Indian Ocean shortly departed their stations for port. But despite this possible setback, a different kind of important launch came on July 13 from Tyuratam. It used the D–1–e vehicle and was named Luna 15. It was put into the usual kind of intermediate orbit from which it was sent toward the Moon. The typical midcourse correction was executed on July 14 and on July 17, it was braked into lunar orbit. Apollo 11 was launched with its human crew toward the Moon on July 16, with the target date of July 20 for landing on the surface. The Soviet flight and its successors of the same series flew a slower course than used previously in order to maximize payload capacity, despite use of a more powerful launch vehicle.

There was some concern in the United States as to whether this somewhat mysterious flight, whose detailed goal had not been revealed, would interfere with the manned mission. All the Russians had said was that Luna 15 was designed to study the space around the Moon, the gravitational field of the Moon, the chemical composition of lunar rocks, and provide surface photography. American astronaut Frank Borman who had recently been in the Soviet Union made a personal appeal to Soviet officials for the orbital elements which had not been announced at first, and asked for assurances that the flight would not interfere with the Apollo mission. He was given the orbital data of 203 by 55 kilometers, with a period of 120.5 minutes, and was told that there was no intention of endangering the Apollo flight.

On July 19, TASS announced an orbital change to an inclination of 126 degrees, with the orbit ranging between 221 and 95 kilometers, with a period of 123.5 minutes. On July 20, this was modified again to an inclination of 127 degrees, and the range from 110 to 16 kilometers, with a period of 114.0 minutes. This happened just before the landing of Apollo 11. It looked like either a Soviet readiness to take high resolution pictures of future landing sites, or a preparation for an immediate landing by Luna 15 itself.

The next Soviet announcement came on July 21, while the Americans were on the lunar surface. Luna 15 had fired a retrorocket and had "reached" the lunar surface in the "preset" area. A total of 86 com-

munications sessions had been held with the craft and it accomplished 52 revolutions of the Moon. The station was described as greatly improved over its predecessors, being able to land in many parts of the Moon through its orbital adjustment abilities. Even at the time there seemed little doubt from the wording of the Soviet statements that Luna 15 was intended to make a soft landing on the Moon to conduct further experiments, and in this it failed. The Jodrell Bank observatory estimated from the Doppler shift of signals that the payload impacted the surface of the Moon with a residual speed of about 480 kilometers an hour, which would seem a good confirmation that the mission was to slow it for a landing, not merely redirect it to impact.

Even with the advantage of hindsight, in the absence of a Soviet explanation, we have no conclusive answer as to the intended mission of Luna 15. On the one hand, there were the Moscow rumors of early July that the Russians would attempt an automated sample return flight, a mission accomplished later by Luna 16. But these rumors require further assessment which will follow in a later chapter of this report on manned flight. On the other hand, the flight might have been intended to land a roving vehicle as did Luna 17. Luna 15 and Luna 17 both flew in retrograde orbits while Luna 16 flew a posigrade orbit. Luna 15 and Luna 17 made landings in daylight portions of the Moon, while Luna 16 made a landing in the night portion. Moreover, the geared electric motors for the Lunokhod drive had already been tested in lunar orbit on board Luna 12 and Luna 14. If the Russians were trying to beat the Americans in returning a lunar sample to Earth, they were cutting it very close by lingering four days in lunar orbit before collecting their sample, so that the sample collection would come after Apollo 11 had gathered samples, even though the Russians with an unmanned vehicle might have made a faster return flight.

B. KOSMOS 300 AND KOSMOS 305

Kosmos 300 was launched on September 23, 1969 to a low Earth orbit. The time of launch and the nature of the debris in Earth orbit both suggested another lunar flight had been attempted which was not successful in leaving Earth orbit. The payload survived separation from the orbital launch platform even though it did not go into deep space, because of the nature of the orbital maneuvers which it was able to make during its four-day life. Because the relation of this flight to phases of the Moon was not like Zond 7, but did resemble Luna 16 and 17, it is a reasonable supposition that this was another in the series begun by Luna 15, and was launched by the D–1–e vehicle.

Kosmos 305 was launched one lunar month after Kosmos 300, coming on October 22, 1969. It may have been even less successful than its immediate forerunner, because the Russians did not announce an orbital period for the payload. This almost certainly means the payload decayed before the end of the first revolution. Some debris remained in orbit about two days, perhaps residue of the carrier rocket and the orbital launch platform of the D–1–e vehicle.

C. LUNA 16

Luna 16 was launched on September 12, 1970 at 1626 Moscow time, and entered a preliminary low Earth orbit from which it was fired

toward the Moon in the second half of its first revolution around the Earth about 67 minutes after launch, using the orbital launch platform technique. Left behind in orbit were the typical 4 meter-diameter by 12 meter-long stage and an irregular launch platform. This stage of about 4,000 kilograms was typical of the D–1–e.

A midcourse correction was made on September 13, and after 26 radio sessions with the payload, it was braked on September 17 into a low circular orbit of the Moon at 110 kilometers an inclination of 70 degrees, and a period of 119 minutes. Further orbital adjustments on September 18 and 19 brought the orbit to between 106 and 15 kilometers, and the inclination to 71 degrees. On September 20, the retrorocket was fired for final descent. At an altitude of 600 meters this engine was turned on again to begin the controlled landing. It was switched off at 20 meters, and two smaller engines were turned on to burn until the altitude was 2 meters. The descent had been controlled by a combination of preprogramed instructions and radar altimeter measuring both distance and rate of descent. By this time 68 radio sessions with Earth had been held. At 0818 Moscow time, Luna 16 was safely on the surface of the Moon on the Sea of Fertility at 0° 41′ S and 56° 18′ E., as planned. To this point the mission of Luna 16 was still undescribed, as were its size, appearance, and equipment.

The first pictures to be released after the landing proved to be only generally indicative of the craft—an artist's impression without reference to the real craft. Later drawings were much more detailed and eventually replicas were put on display, starting with Moscow on November 12, 1970. The craft consisted of a multi-purpose, self-contained landing stage made up of various spherical tanks and cylinders bound together by open trusswork. It had four very short shock-absorber legs. In the lower center was a large bell-shaped nozzle for the main descent and maneuvering engine which was liquid fueled with a multiple burn capability. It was supplemented by two independent lower-thrust braking engines, and various small vernier engines for orientation. The device had chemical batteries and transformers, radios and their antennas to operate in several wave bands, optical and accelerometer sensors for orientation, gyros, computers, timing devices, a heat-regulating system, and a radar altimeter. Some equipment was in the main structure; others were in separate exterior compartments. Specialized to this class of mission, there was an extendable arm which could be controlled from Earth to reach out beyond the immediate blast area of touchdown. At the end of the arm was an elaborate drilling rig which could draw a sample of the lunar soil, and then manipulate it back for insertion into a special container. Telephotometers were placed to guide the Earth-bound remote operator of the drill rig.

Mounted on top of the multi-purpose landing stage was an ascent stage made up of spherical propellant tanks and a liquid-fueled main engine, plus vernier engines for steering. These were all fastened together by exposed trusswork. Atop the propulsion section was an instrument cylinder with its electronic computing equipment, various sensors, gyros, radios, chemical batteries, transformers, and 4 projecting radio antennas. Strapped to it was the actual recoverable portion, a sphere heavily protected by ablation material. Inside was the container to receive the lunar sample in its cylinder, packed parachutes, radio beacon, batteries, and antennas. It is hard to judge the true size

of the total assembly of two stages and associated equipment, but it must have been close to the 4 meters diameter of the D–1–e rocket (also estimated as 3.72 meters), and also stood about 4 meters high.

Because the D–1–e vehicle is used for the third generation series of unmanned lunar programs, we can estimate the weight brought to escape speed to be on the order of 5,000 to 6,600 kilograms. After retrofire to slow into lunar orbit, the weight may lie in the range of 4,000 to 4,500 kilograms. Further braking to achieve a landing should give a number in the range of 1,800 to 2,000 kilograms. These are very rough estimates. In the case of Luna 16, the Russians finally announced a landed weight of 1,880 kilograms.[29]

As events of the flight unfolded at the time, no advance warning was given of the specific intended mission, but over the weeks following, more detailed accounts were made public. The first task of the craft, once on the surface of the Moon, was to review its own housekeeping functions to insure that all subsystems were in working order. It had to establish not only its exact location on the lunar surface, but also find the local vertical. Then the arm attached to the landing stage was extended out, generally beyond the immediate blast area of the braking rocket. Its special drilling unit, consisting of a hollow cylinder with cutters at the end went to work, with controllers on Earth sensing remotely how fast to cut in relation to the apparent hardness of the lunar material. The drill was allowed to cut into a depth of about 35 centimeters. The Russians are not certain whether at this point they reached bed rock or an isolated hard stone. But rather than risk damage to the equipment, drilling ceased. The sample in the tube consisting of soil ranging from fine dust to more granular sand was carried on the same sampler arm up to the ascent stage and inserted into the recovery capsule which was then hermetically sealed.

Then preprogramed information plus instructions from Earth prepared the spacecraft for launch. After 26 hours and 25 minutes on the surface, the ascent stage took off at 1043 Moscow time on September 21, using the descent stage as its launch platform. The lower stage remaining on the Moon continued to broadcast to Earth data on local temperature and radiation conditions.

According to the Bochum radio space observatory in the German Federal Republic, strong and good quality television pictures were returned from the craft. Such pictures were not made available in the United States either by Bochum or by any other source, so the report has to be accepted with reservations.

The return flight to Earth was made without midcourse corrections. In contrast to the Zond flights which were to have been precursors to manned flights, and hence made with as low a G-load, and as low heat load return as possible from the Moon, the Luna 16 payload made a straight ballistic return to Soviet territory. The time and area of recovery was announced in advance by the Soviet Government. As it came closer, the ground complex calculated its point of return with increasing accuracy. On September 24, the recovery capsule with its sealed cylinder of lunar soil was separated by a pyrotechnic device from its lunar launch rocket, while approximately 50,000 kilometers from Earth. The capsule hit the dense atmosphere at 0810 Moscow time.

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[29] TASS, October 3, 1970, 1035 GMT.

After aerodynamic braking, which put a 350 G-load on the capsule, and raised its surface temperature to about 10,000° C., it slowed down still more. At 0814 the braking parachute and then the main parachute were deployed, together with the antenna for the radio beacon. As it came down on its parachute at the predicted location, both aircraft and helicopters of the rescue force heard the radio beacon and made a visual sighting of the parachute. It landed at 0826, and soon was retrieved. The total flight has lasted 11 days, 16 hours.

The landing was announced about two hours after the event with the report the capsule had come through in good condition. No weight for the sample was given at that time. Western observers assumed it was fairly small, perhaps only a kilogram or so. Later it was revealed to be only 101 grams. Even so, this afforded an important resource to analysts in the Soviet Union. After the helicopter pickup, the special factory facility in the area removed the hermetically sealed container with the core sample from the capsule without repressurizing it. The container was then flown to Moscow to the major lunar receiving laboratory. As an aid to quarantine, the container was placed in a stainless steel chamber with glass portholes. Then pumps lowered the pressure to a high vacuum, following which a sterilizing gas was introduced to kill any Earth germs on the exterior of the container. A variety of remote control devices, like those used at Houston, opened the core-containing tube, and passed portions of the lunar material to various sealed sublaboratories equipped with more manipulators and chambers with built-in rubber gloves. Precision scales, electric heaters, binocular microscopes, vibration mills, and special sealed samples in separate bags for biologists and geochemists were all provided. Thin slices were polished to transparency for further detailed analysis. Any outgassing from the lunar material was subjected to 800° C. heat to insure sterility.

The early descriptions of the actual material were very similar to those from Houston—some disagreement over the exact color, and clinging external dust on the container. The color had first been described as dark blue, but later was more generally called gray, with the appearance of being green or brown at some lighting angles. The average density was 1.2 grams per cubic centimeter in original condition, but shook down to about 1.8 grams. Analysis was continuing, and small samples were made available to scientists in other countries, including a direct exchange with the United States.

The many articles by Soviet scientists which discussed Luna 16 put heavy stress on the eventual use of the Luna 16 techniques for exploration of Mars, Venus, and the planetoids. While Luna 16 was extolled as cheaper for exploring the Moon than the manned Apollo flights, the Russians also stated that their exploration of the Moon would use several techniques in the future, including both automated devices and manned expeditions.

1. Comparative Cost of Luna 16 and a Typical Apollo Mission

The question of comparative costs has been raised in both Soviet and U.S. discussions, with some very wide-ranging estimates. There is no definitive answer, but perhaps a reasonable perspective can be suggested.

(a) In the first place, neither the U.S. nor the Soviet program has been aimed at purely scientific objectives. To the degree that their

respective programs have been designed to build a general capability in space flight, or to create an image of success, or to fulfill non-quantifiable goals of exploration, no comparison of scientific returns in relation to the costs is statistically valid anyway.

(b) If one makes the arbitrary and even invalid asumption that the only goal sought is science, then there are still difficulties in the comparison. If the goal was simply to have brought home a token sample, this Soviet Luna approach is cheaper. But if the ability to bring home 101 grams is compared with many tens of kilograms on each flight, the U.S. unit cost per kilogram is lower. The Soviet sample was not only small, but was selected virtually at random. U.S. samples ideally were carefully selected for variety and interest, and could be described and documented as to their original location. Our crews were capable of ranging over a fairly wide territory.

(c) No direct cost comparison is possible between Soviet flights and U.S. flights because the Russians do not make available cost data. Even if they did, very careful definitions would have to be drawn up as to whether costs related to total programs including their research and development, and what arbitrary share of joint costs should be allocated to a particular project such as for flight to the Moon. The closest approach one can make is to consider what it would cost us to conduct a Luna 16-type mission, and then perhaps to compare the out-of-pocket costs for this automated mission with an Apollo mission. The full analysis goes beyond the scope of this study, but a conservative estimate is that a manned Apollo round trip with the maximum amount of supporting equipment and doing many things besides bringing home rock samples costs on the order of $450 million. Using the Saturn I B or Titan III E with Centaur stage, and new lunar landing and return stages would give an out-of-pocket cost of about $100 to $120 million for each Luna 16 type flight if the program contained as many flights as were planned for Apollo. This means an Apollo cost about four times as much as the equivalent of a Luna 16. An Apollo flight brings more than four times the variety and amount of scientific returns as one Luna 16 flight, regardless of the impressiveness of the Soviet automatic system.

(d) As will be developed later in this study, the Soviet Union did not go the Luna 16 route to save money compared with the manned lunar landing route. It also has spent the large sums needed to support a manned lunar landing, but has not produced the visible result in this regard which the United States has achieved. Looking beyond out-of-pocket costs, the United States committed about $35 billion to the Apollo program ($21.35 billion to achieve the first manned landing), and the Russians by spending for both an advanced unmanned and its two manned lunar programs (built around Zond and around the missing G–1–e) probably committed the equivalent of about $49 billion for such programs if these were intended to be of about the same scope and duration as the Apollo program of the United States. This country earlier had program planners who would have been very pleased to have the equivalent of the automated lunar programs undertaken by the Russians (called by the planners, Prospector), but the ultimate decision was we could not afford as many program elements as the Russians have undertaken, and hence these Prospector plans were not implemented with hardware.

D. LUNA 17 AND LUNOKHOD 1

1. Flight of Luna 17

About two lunar months after the launch of Luna 16, Luna 17 was launched at 1744 Moscow time on November 10, 1970. It followed the usual Soviet practice of entering an Earth parking orbit from which the usual Zond probe rocket was fired, leaving behind the separated carrier rocket and orbital launch platform. At a distance of about 289,000 kilometers from Earth the payload was observed by the Kazakh Astrophysical Institute using a telescope fitted with an electronic television enhancement system. Midcourse corrections were conducted on November 12 and 14, and 36 radio sessions were held. On November 15, the braking rocket brought Luna 17 to a circular orbit around the Moon at an altitude of 85 kilometers and a retrograde orbit of 141 degrees to the lunar equator. On November 16, an orbit adjustment lowered the perilune to 19 kilometers.

On November 17, the main braking engine was turned on to begin final descent to the surface, which was reached at 0647 Moscow time, with the location of 38° 17′ N. and 35° W. in the Sea of Rains. The landing stage was essentially the same as used for Luna 16, except that in place of the drilling arm, it carried a flat platform on top with dual ramps on opposite ends. Instead of the Luna 16 payload of an ascent rocket assembly, it carried a mobile vehicle, Lunokhod 1.

2. Description of Lunokhod 1 Roving Vehicle

The Lunokhod 1 was shaped like an old-fashioned bath tub, equipped with eight wheels, four to a side, and a large convex lid to the tub-like compartment. This lid was hinged at one edge to lift up and over exposing on its underside an array of solar cells. The vehicle carried a cone-shaped antenna, a highly directional helical antenna, four television cameras, and special extendable devices to impact the lunar soil for density and mechanical properties tests. Both the landing stage and the roving vehicle carried Soviet metal pennants and coats of arms.

The Lunokhod 1 is undeniably a remarkable vehicle. It was built of unspecified light-weight materials designed to withstand the stresses of flight from Earth and the great extremes of temperatures on the Moon. It had to avoid the use of plastic materials which deteriorate in the radiation environment of space, and also to minimize the use of moving parts which might weld together in a high vacuum. Its eight wheels were independently powered, and a special suspension system was designed to overcome the unevenness of the terrain (lurain) which it might cross. In order to develop the electric motors for the wheels, these were test flown on both Luna 12 and Luna 14, and were found to be successful. The device was controlled by a four-man crew on Earth, and it had the ability to move at two speeds, either continually or in short increments. The device could move forward or backward, and by applying power in opposite directions to the wheels on each side, it could turn in its tracks. Automatic sensors and safety devices would stop the vehicle if they discovered that through inadvertence the human crew on Earth had directed the vehicle up or down too steep a grade, or if it tilted too much to one side. The two gangways on the lander platform were to insure that if a boulder blocked descent in one direction, there would be a second chance to move off the platform.

The four television cameras permitted observation in all directions; also they permitted stereo views; and views could be close up or of distant panoramas. The TV cameras weighed under 1.5 kilograms each, used 2.5 watts of electricity each, and could take pictures with 500 elements for each of 6,000 lines. Data could be sent back to Earth for display at various rate—near real time, or slowly for detailed facsimile reproduction. The vehicle contained various radio systems, computer elements, chemical batteries, a thermal regulating system of pipes circulating fluid and adjustable louvres at the heat exchanger. The experimental gear was fairly diversified. Soil properties could be measured both by the impacting devices and by optical studies of the vehicle tracks. An X-ray spectrometer permitted analysis of soil constituents. Cosmic ray detectors permitted analysis of intensity and energy levels of protons, electrons, and alpha particles, measuring also their direction. Solar flares could be studied. An X-ray telescope permitted detailed search of the heavens for sources, recording the data in the memory units for later broadcasts to Earth.

The lid top to the vehicle during daylight turned over showing the underside of solar cells to expose them to the Sun for current operations and recharging chemical batteries. At night, the lid closed down to minimize damage to the cells, and a radio isotope heat source maintained an adequate level of internal heat to permit the equipment and chemical batteries to survive the lunar night.

3. Review of Operational Life

On November 17, at 0720 Moscow time, radio links with Lunokhod 1 were checked out, and at 0831 the first television pictures were returned. At 0928, Lunokhod 1 descended the steep ramp to reach the surface of the Moon, and began its travels in low gear. Its separate weight was 756 kilograms.

Designed to operate for three lunar days, it continued to function at least in part for 11 or 12 lunar days, making an impressive record by any standards. During the almost year-long period it operated, it occasioned a continuing flood of TASS reports and commentary. Rather than repeat in narrative form the highlights of all the activities reported, much of this information has been summarized in a single table, below, and supplementary comments will be added to supply details and interpretations.

The first operating day was short because it was about half over when the landing was made. Fairly detailed accounts reviewed all the activities for the first three lunar days. After that, the accounts were still frequent but more sketchy on precise numbers and details. Sample reports of the early period follow:

On the first lunar day of operation, between November 17 and 22, when it parked for the lunar night, Lunokhod 1 traveled 197 meters, and in 10 radio sessions with Earth sent back 14 close-up pictures, more than Luna 9 and 13 combined; it also sent back 12 panoramic views.

During the first lunar night, the supplemental French-supplied laser reflector experiment (12 tetrahedral prisms) was tested, and on the first tries, both December 5 and 6, a reflected signal was picked up by the Russians. The French were not successful in their first attempts, and there was speculation in the Western press that the Russians had temporarily withheld precise pointing instructions from the French to enable themselves to be the first to reflect laser signals. During the first lunar night two radio sessions were held with the vehicle to assure that systems were still operating.

On December 9, the solar cell panel was reopened and pointed toward the Sun. On December 10, further travel began, and now at higher speed. On December 14 to 16, no travel was undertaken and the available power was used to operate other experiments. These included generating stereo pairs of pictures, and the X-ray spectrometer experiment. When travel resumed, Lunokhod 1 descended into a crater 3 meters below the level of the Luna 17 lander, and then came out again. By the end of the second operating day, total travel amounted to 1,179 meters, and the vehicle was 1,370 meters away from the lander. Some 33 telepanoramas had been returned to Earth, and additionally some 7 astronomical panoramas had been conducted, to permit a very precise definition of the vehicle's location.

Apparently close to real time television was used to direct the travel, while panoramic studies were conducted for accurate location, topography, and astronomy. Soil chemistry studies took enough power that they were done in periods of no travel. These ceased after the ninth lunar day. Astronomy tests for X-ray measurements and mapping of radio sources were referred to without quantitative counts either after the first three days or in summation. Soil mechanical tests were quantified for the first three days and in total but not mentioned after the ninth day. A few discrepancies between lunar day totals and cumulative totals for travel show up in the announcements. The figure for the eleventh day became a vague "almost 100 meters", which by subtraction can be established as 88. Finally the experiment ceased officially on Ocetober 4, 1971, the anniversary of Sputnik 1. The reason given was that the radio isotope supply used to keep the instrumentation functional despite the rigors of the lunar night had been too reduced in heat output. If so, the complete absence of reports that the vehicle had been contacted during the eleventh lunar night, and the absence of any announcement of its reactivation about September 30, and no reference to any work during the twelfth lunar day strongly suggest that to all intents and purposes, the final performance of Lunokhod 1 came with its shutdown on September 15. It may be that October 4 was the day the team of operators abandoned any further attempt to revive the payload. This minor evasiveness about the timing of its end should not detract from the outstanding accomplishments of the first automated roving vehicle on the Moon.

TABLE 2-7.—SUMMARY RECORD OF THE PERFORMANCE OF LUNOKHOD 1

Lunar day	Vehicle activated	Vehicle shut down	Lunar night contacts	Travel distance (meters)	TV pictures	TV panoramas	Soil tests: Mechanical	Soil tests: Chemical	Astronomy tests
1	Nov. 17	Nov. 22	2 radio, 1 laser	197	14	12	Some	1	Some
2	Dec. 10	Dec. 22	3 radio	1,522	Some	21	do	3	*33
3	Jan. 8	Jan. 20	2 radio	1,936	do	20	*200	10	30
4	Feb. 8	Feb. 19	2 radio	1,573	do	>10	Some	3	Some
5	Mar. 9	Mar. 20	2 radio	2,004	do	Some	do	2	do
6	Apr. 8	Apr. 20	1 radio, 1 laser	1,029	do	do	do	1	do
7	May 7	May 20	1 radio	197	do	do	do	2	
8	June 5	June 18	1 radio	1,559	do	do	do	2	
9	July 4	July 17	1 radio	220	do	do	do	1	do
10	Aug. 3	Aug. 16		215	do				
11	Aug. 31	Sep. 15		88	do	do			
12	Sep. 30	Oct. 4							
Total				10,540	>20,000	206	>500	25	(?)

* Cumulative.

1. The table shows what portion of each lunar day the Lunokhod 1 was activated. During lunar nights while the solar panel was generally closed and no movement occurred, some radio contacts were made to monitor that the vehicle was still operable though quiescent. The listed number of laser reflection tests probably understates what was done, considering both the Russians and the French were interested in testing the reflection.

2. The statistics for each day were compiled by a review of individual TASS bulletins numbering in the scores over a period of 10.5 months. Data became more sparse over time, either because of less news value or as experiments became inoperable.

SOURCES: Mostly from many individual Soviet TASS bulletins. The summary figures on total performance were carried in: Aviatsiya i Kosmonavtika, No. 1, 1972, pp. 33–35.

4. Scientific Findings

By its very nature, the Lunokhod 1 received more continuing coverage in Soviet reports than most other space activities, although as manned stations are put to longer use they reflect some of the same kind of coverage. Many findings were made by Lunokhod 1, only some of which have been published. The data were said to be yielding very detailed topological maps and information on soil structure and composition of the area explored. Features not visible in orbital photographs were found. Instead of the expected basalt plain, the area turned out to be one of complex lava flows with considerable terrace stratification. Also there were folded ridges, with the soil much stronger on top of the ridges.

The instrument named Rifma was used both for measuring the chemical constituents of lunar soil and for interpreting the signals from space received through the telescope. By searching sectors of the sky with this telescope in conjunction with television panoramas of the sky, it was possible to pinpoint X-ray star sources. Measurements were made at levels between 2,000 and 10,000 electron volts in the 1 to 6 angstrom wavelength range. Although normally the Lunokhod 1 cover was closed during lunar nights, there were some special experiments conducted. On February 10, during the lunar day, an eclipse put the vehicle in darkness, and the temperature of the environs dropped from plus 138 degrees Celsius to minus 100 degrees Celsius. This three-hour test of rate of heat loss showed it came through undamaged. In another test, the television system was turned on March 7 during darkness and kept operational to watch the arrival of sunrise.

Several methods of navigation were used during the travels of Lunokhod 1. Laser ranging from the Crimea and also from Pic du Midi in France permitted some very precise measurements. A second approach was the use of dead reckoning, keeping a plot on where the vehicle had been. A third approach was to look for landmarks, and

to estimate from changes in angles to these points the location of the vehicle. A fourth method was to take pictures of star fields and to measure the position of the Sun with a sextant in order to establish the vehicle's location.

The Russians reported the telemetry coming from Lunokhod 1 was so extensive that just the engineering data on the behavior of the wheels produced a greater data flow than was obtained from all spacecraft combined for the years 1957–1960. The vehicle experienced many vicissitudes as it climbed into and out of craters and occasionally met boulders. Sometimes the list was 30 degrees. But by changes of course and backing when necessary, it managed very well. Some areas of dust were found with depths up to 20 centimeters. Then the ninth wheel, a distance measuring device, would not always turn, and other data were required to establish the actual distance covered.

Another interesting phenomenon was measurement of a 1,000-fold increase in the level of low energy protons between April 7 and 10, 1971, after a solar flare had been observed from Earth on April 6.

As the table shows, during the seventh lunar day, little travel was accomplished, and it was feared that deterioration of systems would require restriction of experiments to static ones. But in fact, it came back to good performance the eighth day, with a rapid deterioration thereafter. When the last of its travels were over. it was positioned so that the passive laser reflector supplied by the French could continue to be used for many years to come.

5. *Relative Merits of Manned Versus Unmanned Roving Lunar Vehicles*

The success of Lunokhod 1 inevitably brought back the recurring questions about the relative merits of manned versus automated flights to the Moon. This same kind of analysis has been offered on return of lunar samples. No clear cut answer was possible in that instance, but it was hard to escape the conclusion that Apollo flights at costs up to $450 million each, out of pocket, bringing back 90 kilograms of documented samples selected with some care over many kilometers of terrain (lurain) should have greater scientific merit for analysis than a Luna flight at roughly $100 million or so bringing back about 100 grams from a site selected at random.

The closest parallel between the Luna 17 with Lunokhod 1 mission would be Apollo 15, which was the first to carry a manned roving vehicle:

TABLE 2-8.—COMPARISON OF LUNOKHOD 1 AND APOLLO 15 ROVER

Name	Loaded weight (kg)	Total distance (km)	Useful life (days)	Power source	Control
Lunokhod 1	756	10.5	298	Solar cells	Earth.
Apollo 15 rover	698	64.4	3	Chemical batteries	Astronauts.

SOURCES: Weight of Lunokhod 1: TASS, 8 Feb. 1971, 1152 GMT. Distance for Lunokhod 1: TASS, 9 Oct. 1971, 1222 GMT. Apollo 15 rover data from NASA press kit and subsequent press releases.

It will be observed this is something of an apples and oranges comparison. Time is of the essence with a manned flight to the Moon, and the greatest mobility and practical speed are important. But if there is time for an unmanned vehicle to recharge its batteries, and for sci-

entists on Earth to study each small advance and discovery so that new tasks can be planned with care, then the extended life of the automated vehicle even with slow speed gives a useful result.

Both roving vehicle types were undoubtedly expensive to develop, although the automated Lunokhod system should cost many times more, including its Earth control units. The mission costs probably were on the order of $450 million for the manned rover and $120 million or more for the one-way trip of the automated rover. The contrast is that men can bring observational powers, deploy certain experiments, collect the most interesting rocks, and make some types of repairs on a scale not yet possible under the Soviet plan. But the Soviet plan permitted improvements in performance and interpretations of experiments which could be used to adjust the further program of the same mission working month after month. Essentially, one expenditure for an Apollo flight would do the tasks of both Luna 16 and Luna 17. The American approach brought back better samples and permitted men to have experiences remote study cannot duplicate. The Soviet approach gave more time for intellectual development of surface exploration. It seems reasonable to suggest that the Lunokhod and Apollo approaches are complementary rather than competitive, and in fact even the Russians acknowledge this officially even though they have stressed the comparative cheapness of their automated system.

E. LUNA 18

The next Soviet lunar flight was that of Luna 18, launched on September 2, 1971 at 1641 Moscow time. It was launched with the D–1–e vehicle and carried the same basic third generation bus that had been used since Luna 15. It was observed by Soviet astronomers at a distance of 100,000 kilometers from Earth.

On September 7, Luna 18 was put into lunar orbit at 100 kilometers circular orbit, and an inclination of 35 degrees to the lunar equator, with a period of 119 minutes.

The Russians announced on September 11 that there had been 85 radio sessions with Luna 18, and that it had completed 54 orbits of the Moon. It was then braked to make a landing which occurred at 3° 34′ N. and 56° 30′ E. in high terrain. They said the topography was unlucky, and signals ceased at touchdown at 1048 Moscow time.

F. LUNA 19

Luna 19 was launched on September 28, 1971, using the same launch vehicle and bus as its fairly immediate predecessors. The initial emphasis in the press release was on research from lunar orbit. Astronomers were able to spot Luna 19 on the way to the Moon at a distance of 120,000 kilometers. A day later (September 30), the number of fixes obtained on the payload had risen to 60 as more observatories found it.

On October 3, after 26 radio sessions, the Luna 19 payload was braked into lunar orbit, 140 kilometers circular, at an inclination of 40° 35′, and with a period of 121.75 minutes.

A minor orbital adjustment on October 7 made the orbit 135 by 127 kilometers, and a period of 121 minutes. After that there were progress reports about monthly, but not many details. Through De-

cember 31, 1971, there had been 316 radio sessions with Luna 19. By January 30, it had completed 1,358 orbits, doing studies of magnetic fields, cosmic radiation, solar data, and meteoroids. By March 10, at 1300 Moscow time, the count was up to 1,810 orbits, and 516 radio sessions. Emphasis in the release now was on gravitational studies, which suggested that more elaborate experiments might have shut down by that time. On March 19, the report was amplified to repeat the list of missions which had been mentioned in January, and to say that selective panoramas of the surface had been taken by camera and facsimile transmission to Earth, covering the region from 30° to 60° S. and from 20° to 80° E.

On October 3, 1972, Luna 19 had completed over 4,000 revolutions. It had carried 19 experiments. TASS said it was near the end of its mission. Findings from radio wave propagation suggested a plasma around the Moon from the interactions of solar radiation and the lunar surface. The Luna 19 mission had taught more about the energy spectrum, and the charge components of cosmic rays in space. There had been over 1,000 communications with the payload. The study of orbit changes during the mission had helped to map the location of mascons. On ten occasions, surges of solar activity were studied, with the results combined with data from Venera 7 and 8, Mars 2 and 3, and Prognoz 1 and 2.

Later some more details of the findings were published. The plasma found near the Moon appeared on the lighted side with the greatest concentration at 10 kilometers altitude. It was detected by using a dispersion interferometer sending out coherent signals on 32 cm. and 8 cm., with receipt of the signals on Earth. Some 15 sessions had been held in May and June 1972 to gather the data.

G. LUNA 20

1. Flight of Luna 20

Luna 20 was launched on February 14, 1972 at 0628 Moscow time, using the D–1–e vehicle and the usual orbital platform technique for injection into translunar flight. A midcourse correction was made on February 15, and then it was braked into lunar orbit on February 18. The orbit attained was 100 kilometers circular, at an inclination of 65 degrees and a period of 1 hour 58 minutes. A day later, the perilune was lowered to 21 kilometers. On February 21 at 2219 Moscow time, Luna 20 was braked to a landing at 3° 32′ N., 56° 33′ E. in mountainous terrain near the Sea of Fertility. It may be observed that the landing site was very close to that selected for the failed soft landing of Luna 18. The braking burn took 267 seconds. Free fall then was permitted to an altitude of 760 meters. Here, there was a second burn that lasted until the payload was 20 meters above the surface where the main engine was turned off, and small thrust braking took over. The landing site was about 120 kilometers north of the Luna 16 site, but in uplands rather than in a mare.

2. Surface Activity

After landing, the standard platform turned on its television system to take panoramic pictures of the surroundings. Then it activated its extension arm to place its drill on the most promising spot within reach to drill a sample from hard rock, with the work proceeding in stages. The drilling system used a percussion rotary drill designed to

preserve the natural strength of the rock sample, and oil vapor lubrication to prevent its parts from sticking. After each brief application of the drill, there would be a pause for a fresh television view. The sample acquired was one with both sand and hard rock. The drilling arm had been rigged to emerge vertically from the platform, rotate to the desired azimuth, and then was lowered to the ready position for drilling. All this took 7 minutes. After television inspection, there were 2 more minutes spent to adjust the direction of the drilling arm, and 3 minutes for final descent to surface contact. The drill operated at 500 rpm, and it took just 7 minutes to extract the sample. After this was completed, the arm lifted up the drilling unit with its intact sample to line it up with the recoverable capsule and insert it. This was hermetically sealed. There followed a 20 hour wait to insure that when launch came for the return flight to Earth it would be carried to the selected area of the Soviet Union.

3. Return Flight and Recovery

Launch occurred at 0158 Moscow time on February 23. The sample was well shielded by ablative material on the recovery capsule. After separation of the capsule from the launch rocket, it made a ballistic entry with aerodynamic braking, and then further slowing by parachute. Its radio beacon was picked up by aircraft. The landing took place on an island in the Karakingir river at 67° 34′ E. 48° N. Three tracked rescue vehicles trying to reach it broke through river ice, and pickup had to await the availability of a helicopter and daylight. The bright orange parachute was then spotted. About 5 mm of material had been ablated from the capsule surface. The sealed container with the lunar sample was taken out and transported to the lunar receiving laboratory where 14 hours after the return the contents were put into a steel tray. The landing had occurred at 2212 Moscow time on February 25, 40 kilometers northwest of Dzezkazgan in Kazakhstan. The landing conditions were ones of blizzard and low clouds. The search area had measured 80 by 100 kilometers. This time the entry was at an angle of 60 degrees, providing a lower G load than that experienced by the return of Luna 16. However, temperatures ran higher.

The sample container was opened in a helium atmosphere. The sample itself proved to be lighter in color than that returned by Luna 20. It was described as light to dark brown, and also as light gray, again demonstrating the difficulties associated with describing the colors of most lunar samples.

Later, the Luna 20 return vehicle was referred to as a VLAS (returnable lunar automatic station), said to have considerable microminiaturized equipment to make it function. Luna 16 and 20 were described as essentially the same except for minor regrouping of components to improve conditions. It was noted that this time the landing had been made in daylight in order to gain better quality stereo telephotos of the landing site.

4. Scientific Results

This flight provided an opportunity for further scientific exchanges. The United States was given 2 grams plus photographs, in exchange for 1 gram from Apollo 15. Earlier the United States had supplied material from Apollo 11 and 12 for material from Luna 16. The French had been given material from Luna 16, also, and now received a sample from Luna 20.

Soviet analysis of the sample found traces of 70 chemical elements. The highlands sample, as indicated, was lighter and had more large particles. Their density was described at 1.1 to 1.2 grams/cm^3, compactable to 1.7 to 1.8 grams/cm^3. The rock was called anorthosite.

For the future, the Russians saw opportunities to bring home samples from the far side of the Moon. But this will require a trans-Earth injection burn from lunar orbit on the far-side of the Moon, and may require a lunar orbiting communications satellite correctly positioned as well, to maintain links with Earth.

H. LUNA 21 AND LUNOKHOD 2

1. Flight of Luna 21

Luna 21 was launched on January 1973 at 0955 Moscow time using the D–1–e vehicle and translunar injection from an Earth orbital platform in the regular manner. An orbital correction was made on January 9. The Tadzik observatory tracked the flight from 86,000 kilometers to 224,000 kilometers, using an electronic optical enhancer.

On January 12, Luna 12 was braked into an orbit around the Moon with parameters of 100 to 90 kilometers, an inclination of 60 degrees, and a period of 1 hour, 58 minutes. On January 13 and 14, the perilune was lowered to 16 kilometers, and then on January 16 at 0135 Moscow time, it was braked to a soft landing at the eastern edge of the Sea of Serenity in Le Monnier crater.

Luna 21 circled the Moon 40 times before preparing to land. The braking rocket was fired at 16 kilometers altitude, then going into free fall to an altitude of 750 meters. The second firing lasted to 22 meters altitude when the main engine was cut off and smaller thrusters operated to a height of 1.5 meters where at cut off it was allowed to drop the remaining distance. This would be equivalent to a 40 centimeter drop on Earth.

Pyrotechnics were fired to separate the transported lunar rover from the landing stage.

The landing stage was one of the standard platforms now in regular use. It carried a bas relief of Lenin and the Soviet coat-of-arms.

2. Operations of Lunokhod 2

Lunokhod 2 was an improved roving vehicle of 840 kilograms (compared with 756 for its predecessor). After television inspection of the surroundings and lowering of the landing ramp, Lunokhod 2 rolled down the landing ramp at 0414 to the surface of the Moon. Gear was checked and more television pictures were taken. It also carried a bas relief of Lenin and the Soviet coat of arms. Again, a French-supplied radar reflector was incorporated to aid in laser tracking and distance measuring. It remained stationary 30 meters away from the lander until January 18 to charge batteries after opening its solar panel lid.

On January 18, Lunokhod 2 sent TV panoramas and began to move. It also studied the X-radiation of the Sun and studied soil mechanical properties. More battery charging followed. This time, the rover also had kept its solar panel open during most of the flight from Earth in order to save time in battery charging, folding the lid to closed position only during dynamic operations.

Lunokhod 2 reapproached the lander to within 4 meters to take pictures of it, and then from a distance of 6 meters took a panorama

of the surroundings. It was then moved several meters, going through a narrow passage and turning sharply to get into a good viewing position. As with Lunokhod 1, a complete review of daily Soviet accounts over several months would become tedious, so a summary table will be presented with general comments and interpretations on these data.

TABLE 2-9.—SUMMARY RECORD OF THE PERFORMANCE OF LUNOKHOD 2

Lunar day	Vehicle activated	Vehicle shut down	Lunar night contacts— Radio	Lunar night contacts— Laser	Travel distance (meters)	TV pictures	TV panoramas	Soil tests Mechanical	Soil tests Chemical	Astronomy tests
1	Jan. 16	Jan. 24			1,260					
2	Feb. 8	Feb. 23			9,806					
3	Mar. 11	Mar. 23			16,533					
4	Apr. 9	Apr. 22			8,600					
5	May 8	(June 3)			800					
Total			(?)	>4,000	37,000	>80,000	86	>740	(?)	(?)

NOTES

1. The table shows what portion of each lunar day the Lunokhod 2 was activated. During the lunar nights while the solar panel generally was closed and no movement occurred, there were both radio contacts to monitor quiescent systems and laser reflection tests to measure vehicle location and lunar or Earth celestial mechanics data.

2. The statistics on this operation were not reported in quantitative form except for the distance traveled. The numbers shown were constructed by compiling data from scores of individual TASS bulletins over a period of 4.5 months.

3. While the experiment was reported as concluded on June 3, 1973, this time is suspect since it was in the middle of the lunar night when the vehicle would be inactive anyway. Normally, shut down would come at the end of a lunar day, like May 20 or 21, with the failure discovered at time of revival around June 6 or 7. Since the travel reported for the fifth lunar day was so small, failure may have come as early as the second week in May.

SOURCES: Mostly from many individual Soviet TASS bulletins. The summary figures on total performance were carried as a TASS announcement in Pravda, Moscow, June 4, 1973, p.1.

It was not possible to build quite as specific a table this time as with the previous surface rover. But in general, the distance was three to four times as great; television pictures were four times as numerous; television panoramas were perhaps 40 percent as numerous, soil mechanical tests half again as many, and no counts were provided on other activities although all were carried on and with improved equipment.

It was noted by the Russians that Lunokhod 2 was at work in an area only 180 kilometers north of the landing site of Apollo 17. The region was one of transition from the Sea of Serenity to the Taurus Mountains.

A more detailed description was provided of the functions of the human controllers on Earth. A five-man crew was now used. Commander, driver, navigator, radioman, and engineer. Their task was made more demanding by giving the Lunokhod 2 double the speed of its predecessor. Physiological monitoring was done of the ground crew and they were found to work under heavy stress, yet with their high competence, they remained fairly "cool".

The vehicle had been modified for this mission to add in a higher position an extra television camera so that the Earth driver could see farther ahead and direct the vehicle with more confidence. The pictures formed on the Earth screen once every three seconds.

Another new instrument was an astrophotometer. It was used to determine the night skyglow on the Moon (important to guide planning of future observatories on the Moon which might be discouraged if there developed the news that a dust ring circled the Moon). It also looked for Zodiacal light in the plane of the ecliptic. It also was seeking clarification on the spectral composition of the Milky Way. This

instrument previously had been tested on Kosmos 51 and Kosmos 213 in Earth orbit.

The laser reflector work went even better with this flight, being used successfully both from the Crimea and the French Pic du Midi Observatory. It proved possible to gauge distances from Earth to Moon with an accuracy of 20 to 30 centimeters, and to measure shifts of the Earth's pole of as little as 10 centimeters.

The Lunokhod 2 "9th wheel" soil tester was a conical punch with cruciform blades. As it turned, sinking its blades in the soil, the resistance to displacement and compression could be measured.

Another new device was a magnetometer mounted on a pole projected ahead of the vehicle 2.5 meters. It was applied typically in one crater study in which it moved away from the crater four times at 90 degree angles to measure any associated magnetism.

In a number of tests, the vehicle was repositioned to correct for any solar influences in the soil measurements. In mid-February one day, as it moved, it crossed a one meter long plate with a surface so smooth that no tracks were left—highly unusual in the experience of these operations.

Sky glow tests after sunset showed from 10 to 15 times Earth level suggesting a dust atmosphere.

When Lunokhod 2 went up 25 degree slopes, there was 80 percent slippage in the wheels. On another occasion, the vehicle traveled 800 meters in a single hour. After climbing an 18 degree slope to the rim of a crater, it went down to a depth of 100 meters in the crater to study it; then half way out, the wheels sank to a depth of their hubs, and it had to back off, and find another way out.

In March, the Russians revealed the radioactive heat source used to keep Lunokhod alive during the lunar night. It was Polonium 210, converted from Bismuth, with a half life of 20 weeks. This isotope has a low neutron and gamma ray output and mostly emits alpha particles, minimizing shielding problems.

As the Lunokhod 2 left the seabed and climbed into continental areas, it was at an elevation about 400 meters higher than the Luna 21 lander. A clue to the level of activity was provided by the record of the second lunar day. There had been 6,490 radio commands, 65 hours of communication, including one that lasted 12 hours, with more than 120 turns. The average session had been about 6 hours. For each 10 kilometers traveled, there were over 200 mechanical tests with the rotating penetrometer, as well as continuing magnetic surveys with corrections for solar wind effects. The daytime lunar sky was found to exceed Earth sky luminosity by 13 to 15 fold, giving a poor prognosis for lunar observatories in the future, if the finding was confirmed.

A tectonic fracture 300 meters wide and 16 kilometers long was approached.

An explanation of Soviet picture taking systems was supplied in connection with Lunokhod 2 which helped to explain the not always clear descriptions given in connection with Soviet space flights. There are three kinds. (1) An optical mechanical system for direct images, as used on Luna 9 and later missions for preparing panoramas. They make possible high resolution pictures at low power levels using simple antennas, by scanning only one line at time from a stationary position. (2) Photo television, as used for Luna 3, Zond 3, Luna 12, and Mars

2 and 3. These record pictures on film, which is developed on board and later scanned for facsimile transmission to Earth. (3) Electronic for slow frame television and photo television. While not as fast as television on Earth because of technical complications, it served the purposes of steering Lunokhod 1 and 2 and for making other studies.

In general, the Russians praised their design approach as preferred for some years over the more hasty work that astronauts must perform. They saw coming not only use of roving automated vehicles on Mars or Venus, but also coupling a rover with a sample gatherer to load an Earth return rocket.

On the fourth day, Lunokhod 2 made further studies of the rille it had discovered, with stereo pictures of its walls, physical and chemical studies of the soil and by making a .5 kilometer perpendicular excursion from the rim, and back by the same route to make more precise magnetic measurements. It found one to two-meter sized rocks near the edge of the rille, making this difficult to approach. It did find that magnetism changed significantly in approaching the rille. The conclusion of magnetic studies was that the Moon has a weak global field, which is stronger locally, and that meteorites tend to demagnetize areas they strike. It discovered there was a definite magnetic anomaly associated with the rille up to 150 to 200 meters from it.

While it was announced as resuming travel on May 9, as it left its long study of the rille to move toward the Taurus Mountains, there were no more daily accounts of activity and by subtraction from the total travel the known travel on previous days, it looks as if it moved possibly 800 meters on the ninth, and then traveled no more. The announcement that its mission was complete came on June 3 which should have been some time in the lunar night. Without any progress reports during the intervening 25 days, one suspects the mission terminated without immediate announcement, and the next several weeks of diagnostic work and improvisation failed to revive the vehicle. Even so, it exceeded its designed life of three lunar days and was a more comprehensive mobile laboratory than its predecessor. Apparently, premature failure prevented parking the vehicle to permit continuing use of the French-supplied reflectors for laser experiments.

A more complete review of its equipment and operations did not come until November 1973. The landing site was finally pinpointed at 30° 27′ E. and 25° 51′ N. The principal equipment listed included its magnetometer, Rifma-M X-ray spectral analyzer, its physical-mechanical impact wheel, a special reference plate with 39 shades for comparison by the television cameras, and the Rubin 1 radiometer, an astrophotometer, and the French laser corner reflector. Those devices which were new or additional compared with Lunokhod 1 were the magnetometer, astrophotometer, the Rubin 1, and the improved Rifma. The television equipment was enhanced in capacity and helped by having the cameras placed higher on the vehicle.

The same article reviewed the topography, craters, and rille which were explored and mapped. At the landing site, the soil was found to be 24±4 percent silicon, 8±1 percent calcium, 6±.6 percent iron, and 9±1 percent aluminum. This contrasts with the 10–12 percent iron found by Lunokhod 1. As Lunokhod moved up into the hills, it found that iron dropped to 4±.4 percent and aluminum rose to 11.5±1 per-

cent. Laser ranging proved accurate to 40 centimeters. The Rubin 1 laser emission photodetector returned a radio signal to Earth whenever a beam from Earth hit it. There were more than 4,000 hits, and there were 1,500 photos of the Moon to show the vehicle's location. Sky brightness was measured 14 times.[30]

The Rifma-M fluorescent spectrometer used on Lunokhod 2 was described in greater detail together with its findings on chemical composition of the Moon in 1974.[31]

I. LUNA 22

Luna 22 was launched on May 29. 1974 at 1157 Moscow time using the D-1-e class of vehicle and making use of the standard Earth orbital launch platform technique. It was described as designed to study the Moon and space near the Moon. The Georgia Astrophysical Observatory was able to observe the payload at a distance of 250,000 kilometers from Earth. A path correction was made on May 20. After 23 radio sessions, it was braked into lunar orbit on June 2. The orbit was 220 kilometers circular at an inclination of 19° 35′ to the equator of the Moon, and a period of 2 hours 10 minutes.

The mission was described a few days later as that of continuing the work done by Luna 19, the big orbiter which had preceded it. Its geophysical studies were to include taking pictures of large areas, studying magnetic fields, cosmic radiation, and gravitational data. It was known it would speed up slightly and dip over lunar seas. It was also believed the far side would show a distention of 2 to 4 kilometers.

On June 9. the orbit was modified to 244 by 25 kilometers to permit the taking of high resolution pictures at perilune, and to couple these with altimeter readings and gamma ray analysis of lunar rock composition.

Other orbital activities included measuring meteoritic density and the spectrum of solar cosmic rays and concentration of circumlunar plasma and magnetic fields.

After the picture taking was over, on June 13, the orbit was raised to 299 by 181 kilometers to continue gravitational studies.

The next major announcement came on November 11, 1974 indicating that by 1800 Moscow time on November 11, Luna 22 had completed 1,788 orbits of the Moon and now the orbit had been adjusted to 1,437 by 171 kilometers, at an inclination of 19° 33′, and with an orbital period of 3 hours 12 minutes.

By 1100 Moscow time on April 2, 1975. Luna 22 had completed 2,824 orbits of the Moon, and its orbit was 1,409 by 200 kilometers at a 21° inclination, and still a period of 3 hours 12 minutes. It continued to supply data related to lunar gravity, magnetic fields, and surface relief.

By 1200 Moscow time, June 2, it had completed 3,296 orbits and the Deep Space Communications Center had held 2,175 radio sessions with Luna 22. The full one-year program was completed, but it still functioned.

There was a surprise announcement on September 3, 1975. On August 24. the orbit of Luna 22 had been adjusted to lower the perilune

[30] Pravda, Moscow, November 20, 1973, p. 3, interview with Vinogradov.
[31] Doklady Akademii Nauk SSSR, Vol. 214, No. 1, pp. 71–74.

to 30 kilometers. Here, the camera system was activated to take another photograph for development on board and facsimile transmission to Earth. A good quality image was obtained. Afterwards, the orbit was changed to 1,286 by 100 kilometers, at 21 degrees inclination, and a period of 3 hours. It was unusual in Soviet practice to be able to activate a camera system after a one-year lapse and to carry out all the steps to return a picture to Earth. Regular operations were reported as continuing.

In mid-October, the Luna 22 flight was reviewed, to cover its 15 months of operation. It had observed several hundreds of thousands of square kilometers. Because of the lack of atmosphere, it was able to fly much closer to the surface of the Moon than Earth satellites can approach Earth, hence taking high resolution pictures. These low orbits it intermixed with high orbits for picture taking over larger regions. The satellite studied the composition of lunar rocks based on their gamma radiation, circumlunar plasmas, and solar cosmic rays. It also studied meteoritic density, solar long wave emissions, and Jupiter emissions. It studied mascons. There were 1,500 trajectory measurements made during 2,400 radio sessions with Earth. The controllers sent 30,000 radio commands to Luna 22. It was able to measure meteoritic material down to one one-hundred-trillionth of a gram. Its maneuvering fuel was exhausted on September 2.[32]

The Western press reported mission completion in early November 1975.[33] One radio broadcast from Moscow apparently included a statement to the effect that the mission would prove of great help to future manned flights to the Moon, but it has not been possible to pinpoint the time this statement was made.[34]

J. LUNA 23

Luna 23 was launched on October 28, 1974 at 1730 Moscow time using the D–1–e launch vehicle and the orbital launch platform technique. It was described as intended to do further research into the Moon and of space around the Moon. A telescope equipped with television enhancement at the Zayliskiy Alatav Mountains was able to track the flight. Alma Ata Observatory was able to track it two nights, at 30,000 kilometers and at 200,000 kilometers.

An orbit correction was made on October 31. Then on November 2, the braking rocket was fired to put it into a lunar orbit of 104 by 94 kilometers, at an inclination of 138° to the lunar equator (retrograde). The orbital period was 1 hour 57 minutes.

November 4 and 5 the orbit was adjusted to 105 by 17 kilometers. On November 6, it was further braked to land at 0837 Moscow time in the south part of the Mare Crisium. The landing was achieved and signals returned, but the terrain was unfavorable. The attached drill on the platform was damaged and not able to function. It had been intended to drill a sample to a depth of 2.5 meters, and to test other equipment. As a consequence, communications with Luna 23 were terminated on November 9, after operation of a reduced research program.

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[32] Sotsialisticheskaya Industriya, Moscow, October 15, 1975, p. 3.
[33] Flight International, London, November 6, 1975, p. 705.
[34] Perry, G. E., private communication.

VI. Statistical Tables on Deep Space Missions

The tables which follow are intended to supply a quick reference check on the flights of all nations intended to go to lunar distance or beyond. Table 2–10 summarizes flights which went to lunar distance, or were intended to go there and failed their purpose, to the extent known. Table 2–11 does the same for interplanetary flights. The chronological nature of the tables permits the addition of cumulative national weight totals to the extent known to permit one kind of comparison of relative effort.

TABLE 2-10.—SUMMARY OF LUNAR DISTANCE FLIGHT ATTEMPTS

Launch date	Spacecraft name	Nationality	Weight	Cumulative national weight	Mission	Results
1958						
Aug. 17	Pioneer 0	U.S.	38	38	Orbit Moon	Fail—exploded 16 km up.
Oct. 11	Pioneer 1	do	38	76	do	Fail—climbed 113,830 km, fell back over South Pacific.
Nov. 8	Pioneer 2	do	39	115	do	Fail—climbed 1,550 km, fell near Africa.
Dec. 6	Pioneer 3	do	6	121	Fly by Moon	Fail—climbed 102,320 km, fell back over Africa.
1959						
Jan. 2	Luna 1	U.S.S.R	361	361	Strike Moon	Partial—missed Moon by 5-6,000 km, entered solar orbit.
Mar. 3	Pioneer 4	U.S	6	127	Fly by Moon	Success—passed Moon at 60,050 km, entering solar orbit.
Sep. 12	Luna 2	U.S.S.R	390	751	Strike Moon	Success—struck 435 km from visible center.
Sep. 24	Pioneer P-1	U.S	170	297	Orbit Moon	Fail—exploded in static test before launch.
Oct. 4	Luna 3	U.S.S.R	435	1,186	Photo far side	Succeed—returned pictures of 70 percent of far side of Moon.
Nov. 26	Pioneer P-3	U.S	169	466	Orbit Moon	Fail—shroud tore away in launch, payload impacted near Africa.
1960						
Sep. 25	Pioneer P-30	do	176	642	do	Fail—impacted in Africa.
Dec. 15	Pioneer P-31	do	176	818	do	Fail—climbed 13 km and exploded.
1961						
Aug. 23	Ranger 1	do	306	1,124	Vehicle test	Fail—intended to climb to 1,102,850 km, but stayed in low Earth orbit.
Nov. 18	Ranger 2	do	306	1,430	do	Fail—intended to climb to 1,102,850 km, but stayed in low Earth orbit.
1962						
Jan. 26	Ranger 3	do	330	1,760	TV, hard land	Partial—missed Moon by 36,808 km, no TV picture or landed instruments.
Apr. 23	Ranger 4	U.S	331	2,091	TV, hard land	Partial—timer failed, fell on far side of Moon, no pictures.
Oct. 18	Ranger 5	do	342	2,433	do	Partial—power failure, so missed Moon by 725 km, entered solar orbit.
1963						
Jan. 4	Unannounced	U.S.S.R	1,400?	2,586	Moon soft land	Fail—Earth orbit only.
Apr. 2	Luna 4	do	1,422	4,008	do	Partial—missed Moon by 8,500 km, barycentric or solar orbit.
1964						
Jan. 30	Ranger 6	U.S	365	2,798	TV before strike	Partial—on target, but no pictures taken.
Jul. 28	Ranger 7	do	366	3,164	do	Success—returned 4,308 pictures of Moon to impact.
Dec. 11	Centaur 2	do	952	4,116	Vehicle test	Fail—did not restart and soon fell in Australia.
1965						
Feb. 17	Ranger 8	do	367	4,483	TV before strike	Success—returned 7,137 pictures of Moon to impact.
Mar. 2	Centaur AC 5	do	635	5,118	Vehicle test	Fail—exploded at pad.
Mar. 12	Kosmos 60	U.S.S.R	1,470	5,478	Moon soft land	Fail—Earth orbit only.
Mar. 21	Ranger 9	U.S	366	5,484	TV before strike	Success—returned 5,814 pictures of Moon to impact.
May 9	Luna 5	U.S.S.R	1,476	6,954	Moon soft land	Partial—retrofire failed, impacted Moon.
June 8	Luna 6	do	1,442	8,396	do	Partial—missed Moon by 160,000 km, entered solar or barycentric orbit.

July 18	Zond 3	do	890?	9,286	Photo far side	Success—returned 25 pictures, entered solar orbit.
Aug. 11	Centaur 3	U.S	952	6,436	Vehicle test	Success—reached 820,824 km out with Surveyor dynamic model, in barycentric orbit.
Oct. 4	Luna 7	U.S.S.R	1,506	10,792	Moon soft land	Partial—retro fired early, fell on Moon.
Dec. 3	Luna 8	do	1,552	12,344	do	Partial—retro fired late, fell on Moon.
1966						
Jan. 31	Luna 9	do	1,583	13,927	do	Success—returned 27 pictures from lunar surface.
Feb. 26	Apollo-Saturn 201	U.S	15,331	27,767	Vehicle test	Success—flew suborbitally to land in the Pacific.
Mar. 1	Kosmos 111	U.S.S.R	1,600?	15,527	Moon orbit	Fail—Earth orbit only.
Mar. 31	Luna 10	do	1,600	17,127	do	Succeed—returned physical measurements from lunar orbit.
Apr. 8	Centaur 4	U.S	771	28,538	Vehicle test	Fail—low Earth orbit only.
May 30	Surveyor 1	do	995	29,533	Moon soft land	Succeed—returned 11,237 pictures from lunar surface.
July 1	Explorer 33	do	93	29,626	Moon orbit	Partial—failed to approach Moon at right speed, so in barycentric orbit.
July 5	Apollo-Saturn 203	U.S	26,535	56,161	Vehicle test	Success—simulated in Earth orbit a Saturn V flight.
Aug. 10	Lunar Orbiter 1	do	387	56,548	Moon orbit	Success—returned 414 pictures of potential landing sites on Moon.
Aug. 24	Luna 11	U.S.S.R	1,640?	18,767	Moon orbit	Success—but failed to return pictures from lunar orbit.
Aug. 25	Apollo-Saturn 202	U.S	20,275	76,823	Vehicle test	Success—simulated reentry in suborbital flight.
Sep. 20	Surveyor 2	do	1,000	77,823	Moon soft land	Partial—stabilization failed, struck Moon.
Oct. 22	Luna 12	U.S.S.R	1,625?	20,392	Moon orbit	Success—returned pictures of Moon.
Oct. 26	Centaur 5	U.S	726	78,549	Vehicle test	Success—mass model of Surveyor carried to 465,032 km.
Nov. 6	Lunar Orbiter 2	do	390	78,939	Moon orbit	Success—returned 422 pictures of Apollo sites, far side.
Dec. 21	Luna 13	U.S.S.R	1,595?	21,987	Moon soft landing	Success—returned pictures and soil density measures.
1967						
Jan. 27	Apollo-Saturn 204	U.S	20,412	99,351	Capsule test	Fail—Burned on pad in exercise.
Feb. 5	Lunar Orbiter 3	do	385	99,736	Moon orbit	Success—returned 307 pictures of Apollo sites.
Apr. 17	Surveyor 3	do	1,035	100,771	Moon soft land	Success—returned 6,315 pictures, dug soil with shovel.
May 4	Lunar Orbiter 4	do	390	101,161	Moon orbit	Success—returned 326 pictures of large areas of the Moon.
July 14	Surveyor 4	do	1,039	102,200	Moon soft land	Partial—signals ceased at touchdown on Moon.
July 19	Explorer 35	do	104	102,304	Moon orbit	Success—returned data from lunar orbit.
Aug. 2	Lunar Orbiter 5	do	390	102,694	do	Success—returned 424 pictures including much of far side.
Sep. 8	Surveyor 5	U.S	1,005	103,699	Moon soft land	Success—returned 18,006 pictures, chemical analysis of soil.
Nov. 7	Surveyor 6	do	1,008	104,707	do	Success—returned 30,065 pictures, chemical and mechanical soil study.
Nov. 9	Apollo 4	do	42,506	147,213	Vehicle test	Success—simulated full lunar return reentry in Earth orbit.
1968						
Jan. 7	Surveyor 7	do	1,040	148,253	Moon soft land	Success—returned 21,274 pictures, chemical analysis of soil from trench it dug.
Jan. 22	Apollo 5	do	14,379	162,632	Vehicle test	Success—tested lunar module in Earth orbit.
Mar. 2	Zond 4	U.S.S.R	5,800?	27,787	do	Partial—flew to lunar distance but recovery in doubt.
Apr. 4	Apollo 6	U.S	42,577	205,209	do	Partial—did not go to lunar distance, but recovered payload.
Apr. 7	Luna 14	U.S.S.R	1,615?	29,402	Moon orbit	Success—returned data on lunar mass distribution.
Sep. 14	Zond 5	do	5,800?	35,202	Circumlunar	Success—ballistic reentry with biological subjects and pictures.
Oct. 11	Apollo 7	U.S	20,577	225,786	Manned test	Success—flew in Earth orbit.
Nov. 10	Zond 6	U.S.S.R	5,800?	41,002	Circumlunar	Success—lifting reentry with biological specimens and pictures.
Dec. 21	Apollo 8	U.S	43,654	269,440	Moon orbit	Success—men in lunar orbit and recovered.

TABLE 2–10.—SUMMARY OF LUNAR DISTANCE FLIGHT ATTEMPTS—Continued

Launch date	Spacecraft name	Nationality	Weight	Cumulative national weight	Mission	Results
1969						
Mar. 3	Apollo 9	U.S.	47, 167	316, 607	Manned test	Success—tested lunar module rendezvous, crew recovered.
May 18	Apollo 10	do	48, 638	365, 245	Moon orbit	Success—tested lunar module rendezvous at Moon, crew recovered.
July 13	Luna 15	U.S.S.R	5, 800?	46, 802	Moon soft land	Partial—lunar orbit success, but landing failed.
July 16	Apollo 11	U.S.	49, 698	414, 943	do	Success—first manned landing on Moon and return.
Aug. 7	Zond 7	U.S.S.R	5, 800?	52, 602	Circumlunar	Success—lifting reentry of photographs.
Sep. 23	Kosmos 300	do	5, 800?	58, 402	Moon soft land	Fail—Earth orbit only.
Oct. 22	Kosmos 305	do	5, 800?	64, 202	do	Fail—Earth orbit only.
Nov. 14	Apollo 12	U.S.	49, 804	464, 747	do	Success—manned lunar landing and return with part of Surveyor 3.
1970						
Apr. 11	Apollo 13	U.S.	49, 990	514, 737	Moon soft land	Partial—explosion in service module limited flight to circumlunar; crew saved.
Sep. 12	Luna 16	U.S.S.R	5, 800?	70, 002	do	Success—made automated sample collection, returned it to Earth.
Oct. 20	Zond 8	do	5, 800?	75, 802	Circumlunar	Success—ballistic reentry with photographs.
Nov. 10	Luna 17	do	5, 800?	81, 602	Moon soft land	Success—landed automated roving vehicle for long term exploration.
1971						
Jan. 31	Apollo 14	U.S.	46, 346	561, 083	do	Success—manned lunar landing and return.
July 26	Apollo 15	do	52, 759	613, 842	do	Success—manned lunar landing, roving vehicle, safe return.
Sep. 2	Luna 18	U.S.S.R	5, 800?	87, 402	do	Partial—lunar orbit success, but crashed on landing.
Sep. 28	Luna 19	do	5, 800?	93, 202	Moon orbit	Success—returned photographs and other data.
1972						
Feb. 14	Luna 20	do	5, 800?	99, 002	Moon soft landing	Success—made automated sample collection, returned it to Earth.
Apr. 16	Apollo 16	U.S.	48, 606	662, 448	do	Success—manned lunar landing, roving vehicle, safe return.
Dec. 7	Apollo 17	do	46, 825	709, 273	do	Success—manned lunar landing, roving vehicle, safe return.
1973						
Jan. 8	Luna 21	U.S.S.R	5, 800?	104, 802	do	Success—landed automated roving vehicle for long term exploration.
June 10	Explorer 49	U.S.	328	709, 601	Moon orbit	Success—radio astronomy from far side of Moon.

1974						
May 29	Luna 22	U.S.S.R.	5,800?	110,602	do	Success—returned pictures and data.
Oct. 28	Luna 23	do	5,800?	116,402	Moon soft land	Partial—landed safely, but drill damaged so no sample returned to Earth.

NOTES

1. The table includes all known attempts to send payloads to the Moon or to distances from Earth equal to the distance of the Moon from Earth, together with test flights in Earth orbit of lunar-associated hardware. It cannot include Soviet flight failures which did not reach Earth orbit because these are not in the public domain.

2. Weights listed are in kilograms, with a second column showing a running total of kilograms for all flights to data of the same national origin.

3. In a very few instances, the mission has been assigned by inference, in terms of the context of the time in which it took place.

4. The test of success or failure is somewhat arbitrary. Any flight staying in relatively low Earth orbit as well as not achieving Earth orbit is counted as a failure. Flights which at least approached the Moon, although not achieving the estimated goal received the rating of partial success.

5. The Soviet label Luna was applied after the fact to the first flights which at the time were simply called Cosmic Rockets, with the third one called an Automatic Interplanetary Station (AIS 1). Luna 1 was also called Mechta (Dream).

SOURCES: Soviet data are from Soviet TASS bulletins for the most part, supplemented by inferential judgments that some Earth orbital flights were almost certainly lunar attempts which failed, based upon the timing of the launch, the nature of the debris in Earth orbit, the launch vehicle used, and the orbital path chosen. U.S. data are based mostly on NASA press releases, although the first lunar attempt was sponsored and reported on by the Advanced Projects Research Agency (ARPA) of the Department of Defense before the creation of NASA. Estimated weights of lines 11, 12, 13 and 14 by D. R. Woods, whose generalized estimate on later Luna and Zond flights also has been used.

TABLE 2-11.—SUMMARY OF PLANETARY DISTANCE FLIGHT ATTEMPTS

Launch date	Spacecraft name	Nationality	Weight	Cumulative national weight	Mission	Results
1960:						
Mar. 11	Pioneer 5	U.S.	43	43	Interplanetary toward Sun.	Success—returned data to 36.2 million kilometers.
Oct. 10	Unacknowledged	U.S.S.R.	640?	640?	Mars	Fail—did not reach Earth orbit.
Oct. 14	Unacknowledged	do	640?	1,280	do	Fail—did not reach Earth orbit.
1961:						
Feb. 4	Tyazheliy Sputnik 4	do	640?	1,920	Venus	Fail—Earth orbit only.
Feb. 12	Venera 1	do	644	2,564	do	Partial—Communications failed; passed Venus at 100,000 km.
1962:						
July 22	Mariner 1	U.S.	202	245	Venus flyby	Fail—destroyed at 160 km. altitude.
Aug. 25	Unacknowledged	U.S.S.R.	890?	3,454	Venus	Fail—Earth orbit only.
Aug. 27	Mariner 2	U.S.	203	408	Venus flyby	Success—passed Venus at 34,853 km.
Sept. 1	Unacknowledged	U.S.S.R.	890?	4,344	Venus	Fail—Earth orbit only.
Sept. 12	Unacknowledged	do	890?	5,234	do	Fail—Earth orbit only.
Oct. 24	Unacknowledged	do	890?	6,124	Mars	Fail—Earth orbit only.
Nov. 1	Mars 1	do	894	7,018	do	Partial—communications failed, passed Mars at 193,000 km.
Nov. 4	Unacknowledged	do	890?	7,908	do	Fail—Earth orbit only.
1963:						
Nov. 11	Kosmos 21	do	890?	8,798	Venus test	Fail—Earth orbit only.
1964:						
Mar. 27	Kosmos 27	do	890?	9,688	Venus	Fail—Earth orbit only.
Apr. 2	Zond 1	do	890?	10,578	do	Partial—communications failed, passed Venus at 100,000 km.
Nov. 5	Mariner 3	U.S.	261	669	Mars flyby	Fail—shroud did not separate, thrown into wrong orbit.
Nov. 28	Mariner 4	do	261	930	do	Success—returned 22 pictures.
Nov. 30	Zond 2	U.S.S.R.	890?	11,468	Mars	Partial—communications failed, passed Mars at 1,500 km.
1965:						
July 18	Zond 3	do	890?	12,358	Mars test	Success—returned 25 pictures of Moon far side, retransmitted from increasing distances.
Nov. 12	Venera 2	U.S.S.R.	963	13,321	Venus flyby	Partial—communications failed, passed Venus at 24,000 km.
Nov. 16	Venera 3	do	960	14,281	Venus land	Partial—communications failed, struck Venus 450 km. from visible center.
Nov. 23	Kosmos 96	do	960?	15,241	Venus	Fail—Earth orbit only.
Dec. 16	Pioneer 6	U.S.	61	991	Interplanetary toward Sun.	Success—returned data.
1966: Aug. 17	Pioneer 7	do	61	1,052	Interplanetary away from Sun.	Success—returned data.

1967:						
June 12	Venera 4	U.S.S.R	1, 106	16, 347	Venus land	Success—returned direct readings of atmosphere to 25 Km. altitude.
June 14	Mariner 5	U.S	245	1, 297	Venus flyby	Success—returned data, passed Venus at 4,094 km.
June 17	Kosmos 167	U.S.S.R	1, 100?	17, 447	Venus	Fail—Earth orbit only.
Dec. 13	Pioneer 8	U.S	66	1, 363	Interplanetary away from Sun.	Success—returned data.
1968: Nov. 8	Pioneer 9	do	67	1, 430	Interplanetary toward Sun.	Success—returned data.
1969:						
Jan. 5	Venera 5	U.S.S.R	1, 130	18, 577	Venus land	Success—returned direct readings of atmosphere to near surface.
Jan. 10	Venera 6	do	1, 130	19, 707	do	Success—returned direct readings of atmosphere to hear surface.
Feb. 24	Mariner 6	U.S	380	1, 810	Mars flyby	Success—returned 24 pictures and other data.
Mar. 27	Mariner 7	do	380	2, 190	do	Success—returned 31 pictures and other data.
Aug. 27	Pioneer E	do	66	2, 256	Interplanetary at Earth orbit.	Fail—destroyed by range safety.
1970:						
Aug. 17	Venera 7	U.S.S.R	1, 180	20, 887	Venus soft land	Success—sent back data from atmosphere and surface of Venus.
Aug. 22	Kosmos 359	do	1, 180	22, 067	do	Fail—Earth orbit only.
1971:						
May 8	Mariner 8	U.S	1, 029	3, 285	Mars orbit	Fail—fell in Atlantic Ocean.
May 10	Kosmos 419	U.S.S.R	4, 650?	26, 717	Mars soft land	Fail—Earth orbit only.
May 19	Mars 2	do	4, 650	31, 367	do	Partial—returned data from orbiter, but lander destroyed.
May 28	Mars 3	do	4, 650	36, 017	do	Success—returned orbital data and survived landing.
May 30	Mariner 9	U.S	1, 030	4, 315	Mars orbit	Success—returned 6,786 pictures of Mars.
1972:						
Mar. 3	Pioneer 10	do	258	4, 573	Jupiter flyby	Success—returned pictures and other data.
Mar. 27	Venera 8	U.S.S.R	1, 180?	37, 197	Venus soft land	Success—atmospheric data and soil analysis returned.
Mar. 31	Kosmos 482	do	1, 180?	38, 337	do	Fail—Earth orbit only.
1973:						
Apr. 6	Pioneer 11	U.S	259	4, 832	Jupiter, Saturn flyby	Success—returned Jupiter pictures and data; Saturn not yet reached.
July 21	Mars 4	U.S.S.R	4, 150?	42, 527	Mars orbit	Partial—returned data in flyby, bit did not enter orbit.
July 26	Mars 5	do	4, 150?	46, 677	do	Success—returned data and pictures.
Aug. 6	Mars 6	do	4, 150?	50, 827	Mars soft land	Partial—returned data from flyby, but lander signals ceased.
Aug. 9	Mars 7	do	4, 150?	54, 977	do	Partial—returned data from flyby, but lander missed by 1,300 km.
Nov. 3	Mariner 10	U.S	504	5, 336	Venus, Mercury flyby	Success—returned pictures from Venus and three times pictures from Mercury.
1974: Dec. 10	Helios 1	German Fed. Rep./U.S	370	5, 706	Sun approach	Success—returned data.

TABLE 2-11.—SUMMARY OF PLANETARY DISTANCE FLIGHT ATTEMPTS—Continued

Launch date	Spacecraft name	Nationality	Weight	Cumulative national weight	Mission	Results
1975:						
June 8	Venera 9	U.S.S.R.	5,000?	59,977	Venus soft land	Success—returned pictures and other data.
June 14	Venera 10	do	5,000?	64,977	do	Success—returned pictures and other data.
Aug. 22	Viking 1	U.S.	3,440	9,146	Mars soft land	En route.
Sep. 9	Viking 2	do	3,440	12,586	do	En route.

NOTES

1. The table includes all known attempts to send payloads to the planets or into solar orbit, not including those intended to go to the Moon which only incidentally may have escaped barycentric orbit to enter heliocentric orbit. It cannot include additional Soviet flight failures which did not reach Earth orbit, when not in the public domain. The only year in which there had been persistent reports of Soviet intentions to launch planetary flights for which there is no public record of failures is 1969. This could mean that Mars flights using the D-1-e vehicle began in that year, but failed to reach Earth orbit.

2. Weights listed are in kilograms, with a second column showing a running total of kilograms for all flights to date of the same national origin.

3. In a few instances, the mission has been assigned by inference, in terms of the context of the time in which it took place. Some of the Soviet flights to the planets may have been orbiters or landers, but no attempt has been made to guess the mission other than that of the planet name.

4. The test of success or failure is somewhat arbitrary. Any flight staying in relatively low Earth orbit as well as those not achieving Earth orbit are counted as failures. Flights at least approaching interplanetary distances although not achieving their estimated goal received the rating of partial success.

SOURCES: Soviet data are from Soviet TASS bulletins for the most part, supplemented by inferential judgments that some Earth orbital flights were almost certainly planetary attempts which failed, based on the timing of the launch, the nature of the debris in Earth orbit, the launch vehicle used, and the orbital path chosen. U.S. data are based mostly on NASA press releases. Weight estimates for the more recent Mars and Venus flights by the Russians have been varied from the weight of Mars 2 and 3 at the suggestion of D. R. Woods and C. P. Vick, to reflect approximate energy requirement effects on payload.

CHAPTER THREE

PROGRAM DETAILS OF MAN-RELATED FLIGHTS

By Marcia S. Smith*

I. Early Years

Although principal attention in this report will be given to man-related flights occurring between 1971 and 1975, it is useful to understanding the program in its entirety to review accomplishments prior to 1971. Thus a summary of the earlier period is included in this section.

A. ADVANCE PREPARATIONS FOR MANNED FLIGHT

Through the 1950's, the Soviet Union fired an increasingly ambitious series of vertical probe rockets from the Kapustin Yar launch site with adapted military rockets, apparently ranging from modified versions of the German V–2 on up through the medium range surface-to-surface missile which the Western powers call the SS–3 or Shyster. Shyster was the immediate forerunner of the SS–4 or Sandal, famous for its involvement in the Cuban missile crisis and for launching the small Kosmos payloads from Kapustin Yar and Plesetsk.

While the United States was making tests with monkeys and apes, the Russians concentrated on dogs, and occasionally sent smaller animals. By 1952, the Soviet Union claimed to have sent 12 animals up in 18 flights to altitudes of 96 km. The effort had improved to the point that in the spring of 1957, a single rocket with a payload of 2,195 kg had carried five dogs. That June the Russians announced that dogs would participate in the Soviet part of the IGY program. On August 27, 1958, the dogs Belyanka and Pestraya were flown to 452 km in a payload of 1,690 kg. On July 2, 1959, in a payload of 2,000 kg, Otvazhnaya and another dog were flown to 241 km. On July 10, 1959, Otvazhnaya and several other dogs were flown to 211 km in a payload of 2,200 kg. Otvazhnaya made yet another flight on June 15, 1960, this time accompanied by another dog and a rabbit. This rocket had a payload of 2,100 kg and was flown to 221 km. These and other repetitive flights gave opportunities for testing a variety of life support component systems and for linking the behavior of animals, even if briefly, to the hazards of rocket acceleration, radiation, micrometeorites, weightlessness and recovery.

1. *Sputnik 2*

The first flight to carry an animal to orbit was described in Chapter Two (page 83). The cabin carrying Layka was cylindrical in shape, hermetically sealed with a regenerating system for the air, a thermal

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regulation system, and was supplied with food. The dog was wired so as to radio back to Earth its pulse, respiration, blood pressure, and electrocardiograms. The cabin environmental parameters were also telemetered back to Earth. Automatic devices controlled the quality, component gases, temperature, and circulation of the air supply. The dog was trained over a period of time in preparation for the flight, including exposure to vibration, and periods up to weeks in a sealed cabin of small dimensions.

Layka withstood the launch and flight environment successfully, returning considerable useful data. However, because the ship was only powered by chemical batteries and was not designed for recovery, after one week, a prearranged system killed the dog and terminated that part of the experiment.

B. THE KORABL SPUTNIK PRECURSORS TO VOSTOK

1. Korabl Sputnik 1

By adapting the A–1 vehicle, earlier used for direct ascent flights to the Moon, the Soviet Union was able to create an Earth orbital system which could carry at least 4,700 kg to low orbit. This found its first successful use on May 15, 1960 with the launch of Korabl Sputnik 1. It was described as weighing 4,540 kg consisting of 1,477 kg of instruments and equipment and a self-sustaining biological cabin of 2,500 kg. In the cabin was the dummy of a man with characteristics of body construction and function like a man, designed to check on the operation of the life support system and stresses of flight. The ship radioed both extensive telemetry and also prerecorded voice communications. The Russians some years later told how they wanted to avoid Western claims that they had flown a man on this mission and lost him, so rather than taping a pilot's voice sending typical flight data, they installed the tape of a Russian choral group singing.

After four days of flight, the reentry cabin was separated from its service module and retrorockets were fired. Unfortunately, the attitude was incorrect, for the cabin moved to a higher orbit, and it was five years before it finally decayed from orbit.

2. Korabl Sputnik 2

This launch came on August 19, 1960 and carried the dogs Strelka and Belka. This time the period of flight was reduced to one day to minimize the risks of equipment malfunction, and recovery was successfully accomplished, for the first time in history, with the two dogs becoming national heroes and put on display, obviously healthy despite their experience.

3. Korabl Sputnik 3

Apparently this launch of December 1, 1960 was a repeat of the previous flight except that the perigee was lowered to assure automatic decay within the reserve capacity of the life support system. After one day, retrofire was ordered, but the angle may have been too steep, for the cabin was burned beyond successful recovery. The dogs Pchelka and Mushka became the first important casualties of orbital flight.

4. Korabl Sputnik 4

Launched on March 9, 1961, this flight carried both a dummy cosmonaut and the dog Chernushka. Successful recovery was made after a single orbit.

5. Korabl Sputnik 5

On March 25, 1961 the fifth in this series of flights was launched, again carrying a dummy and a dog, Zvezdochka. As with Korabl Sputnik 4, recovery was made after one orbit.

This brought the Russians to the point where they had a large backlog of short vertical probe biological flights, with synoptic geophysical data, the Sputnik 2 data from a week of flight carrying a dog, and five actual manned-precursor flights, three of which were recovered, including four of the six dogs used. Not only was a ship in excess of 4,500 kg fairly commodious, but it provided a fair amount of redundancy. The dogs not only provided telemetered data and usually were available for post-flight tests, but all the Korabl Sputniks had provided live television coverage from orbit, permitting further examination of their state during flight. Rumors were strong that manned flights were about to begin.

C. THE VOSTOK PROGRAM

1. Vostok 1

On April 12, 1961, Major Yuriy Alekseyevich Gagarin became the first man to orbit Earth. His ship, Vostok 1 (code named Kedr) made a single orbit from Tyuratam and was recovered in Kazakhstan. The electrifying news produced the same kind of shock waves in the world as Sputnik 1 had, despite the advance notice which should have been gleaned from the Korabl flights.

Vostok 1 was launched by an A–1 rocket, and the spacecraft consisted of a near-spherical cabin covered with ablative material, with three small portholes for vision, and external radio antennas. The capsule contained a life support system, radios, instrumentation, and an ejection seat both for escape on the launch pad and as a part of the optional recovery system. The manned cabin was attached to a service module resembling two truncated cones base to base, with a ring of gas pressure bottles on the upper cone close to the cabin. This module carried a considerable weight of chemical batteries, orientation rockets and the main retro system, plus added support equipment for the total system.

On launch, all five engines of the booster rocket fired, and then the four outer sets of tankage and engines fell away, leaving the central sustainer engine still burning. This stage also was abandoned suborbitally, and the upper lunar stage then fired to place itself and the payload in orbit. After burnout, this stage was separated from the payload, and continued in its own orbit a derelict, to decay after a few days.

The payload was allowed to tumble slowly to even out heat loads, but could be stabilized on command for observation of the Earth, signal transmission, and most importantly for correct retrofire on reentry. As on the precursor flights, television was transmitted from the ship.

2. Vostok 2

Major German Titov became the second man to reach orbit on August 6, 1961, remaining up for a day to complete 17 orbits. In most respects the flight was like that of Vostok 1. There is some inconsistency in Soviet accounts with regard to the final phase of recovery in the Vostok program. The implication, although contradicted by other reports, is that Gagarin rode in his ship all the way to the surface of the Earth. But is seems clear that from Titov on through the rest of the Vostok program as 7,000 meters the cosmonaut fired open the hatch and then the ejection seat to come down separately from the main cabin. The cabin, after being slowed by air pressure and protected by ablative material, apparently still struck ground hard enough that even the cosmonaut in a contoured couch would not enjoy the landing. Like the dogs which preceded them, most of the cosmonauts were fired out free from the main ship on their seat, which was mounted on rails pointed toward an escape hatch. After coming well clear, the cosmonaut would then free himself from his seat and come down on a personal parachute.

3. Vostok 3

Major Andriyan Nikolayev was launched on August 11, 1962 into a flight which lasted four days. It can be noted that a flight of similar duration had already been made by a Kosmos military observation satellite using essentially the same hardware but without a life support system; and Korabl Sputnik 1 with the complete Vostok equipment had flown for four days when retrofire occurred. All the Vostoks flew in orbits which would experience natural decay in less than ten days. From the outset every flight carried life support of air, water, food, and electricity to last for ten days, even though no flight lasted that long.

4. Vostok 4

Lieutenant Colonel Pavel Popovich was launched August 12, just a day after Vostok 3, into a close co-orbit so that the two ships approached within 6.5 km of each other in clear visible range. This was impressive both in terms of the ground support at the launch site in readying the facilities for so quick a turnaround (unless two pads were used), and also for the accuracy in timing the launch and controlling the flight parameters to guide the second ship to the same location as the first. This group flight was heralded as a portent of future dockings.

5. Vostok 5

On June 14, 1963, Lieutenant Valeriy Bykovskiy was launched into orbit for five days of flight, matching the time of a predecessor Kosmos military observation satellite. This set a Soviet manned duration record of 119 hours, 6 minutes—not exceeded until Soyuz 9.

6. Vostok 6

It is possible that this launch was a day late, because it went up on June 16, 1963, and on an orbit which would not permit a sustained rendezvous with Vostok 5. The orbit did, however, permit a brief pass at a distance of only 5 km. The pilot was Valentina Tereshkova, the only woman to fly in space to date, and she remained in orbit for three

days. In contrast to the other cosmonauts who were experienced military test pilots, Ms. Tereshkova had worked in a textile factory, took up sports parachuting, and then was trained for her flight. Although she did not have the background of experience common to her Russian and American counterparts, she gained more orbital experience in time than all the flights in the U.S. Mercury program combined. Her flight emphasized that the Vostok system was designed to maximize use of automatic devices, with manual override to be used only in emergencies or experimentally. This feature prevailed through later Soviet programs as well, as all systems have been tested through complete missions unmanned first. It also strengthens the supposition that the transition from Vostok flights to Kosmos military photographic recoverable flights made a minimum of redesign necessary. Measurements on the Kosmos flights by Alan Pilkington, formerly of the Scarborough Planetarium, in England have revealed they are of the same dimensions and brightness as the Vostok payloads.

D. KOSMOS PRECURSORS TO VOSKHOD

On October 6, 1964, Kosmos 47 was put into an orbit 177 x 413 km and after just one day was retrofired to come back to Earth while its carrier rocket flew for eight days. Just six days later a manned flight (Voskhod 1) came with elements of 178 x 409 km and also stayed up one day.

On February 22, 1965, Kosmos 57 was put into an orbit 175 x 512 km. This time something went wrong, for the payload was exploded in orbit. Voskhod 2 did not follow as closely after this precursor as had happened the previous fall. One can surmise that it required a little time to determine that whatever went wrong with Kosmos 57 would be unlikely to occur in the manned flight to follow. Hence the follow-up flight was delayed 24 days and then entered a 173 x 495 km orbit.

E. THE VOSKHOD PROGRAM

1. Voskhod 1

Voskhod 1 was launched on October 12, 1964, and based upon information released after the fact, we can determine that it was put up by an A–2 launch vehicle, which permitted increasing the payload weight from the 4,700 kg range to 5,320 kg. The payload itself has been shown only while covered with its launch shroud, but this was so similar to that of the Vostok series that Voskhod seems to be only a modified Vostok.

The principal modification of this first flight was removal of the heavy ejection seat on its rails. Then within the approximately 2.5 meter sphere of the cabin, it was possible to place three seats side-by-side, but with the center seat raised. By this time such confidence had been gained in the reliability of the basic system, that the cosmonauts did not wear cumbersome protective space suits and helmets, but comfortable coveralls. This practice was followed until the Soyuz 11 tragedy, when the three-man crew died due to a pressure leak in their cabin. Without ejection seats, the landing of the ship with crew on board was eased by use of a final braking rocket.

Voskhod 1 was the first multi-manned flight. The crew was led by Colonel Vladimir Komarov, accompanied by a military physiologist,

Lieutenant Boris Yegorov, and a civilian technical scientist, Konstantin Feoktistov. Although the flight lasted only one day, the special crew made it possible to obtain much more comprehensive medical data as well as operate more complex checks on the payload systems and external experiments. The flight also returned live television pictures from orbit.

There is an interesting political sidelight to this mission, for while in orbit Premier Khrushchev sent congratulations to the crew and promised to see them on the reviewing stands in Moscow on their return. They landed less than 24 hours later, but when they reached Moscow, Mr. Khrushchev had been replaced by Party Secretary Brezhnev and Premier Kosygin.

2. Voskhod 2

Still another variant of the original Vostok hardware was provided by this flight which was launched on March 18, 1965. Again the A–2 vehicle was used, and the payload weight was raised to 5,682 kilograms. Although no pictures of the actual payload have been released, the shroud view in the assembly building showed a large bulge well forward. This flight carried only two seats, and added instead an extendable air lock to permit egress into space without evacuating the main cabin of air. An obscure Soviet photograph recently became available showing a Voskhod training exercise using a Vostok-shaped cabin.

The ship was commanded by Colonel Pavel Belyayev, the first cosmonaut with a naval air force background, accompanied by Lieutenant Colonel Aleksey Leonov. Leonov won a place in history by becoming the first man to perform extra-vehicular activity (EVA). During flight he donned a completely self-contained life support system back pack. Having switched to a supply of air enriched with oxygen in order to purge much of the nitrogen from his blood, he then entered the extendable air lock, sealing the hatch behind him, and then after depressurization opened the second hatch to look out into space. Finally he pushed free to float at the end of a tether line in the weightless, airless medium of space, with his eyes shielded from the Sun by a special visor. Beneath him in a few minutes passed a good part of the Soviet Union.

The event was recorded by a preplaced external television camera, and he also took along a hand-held motion picture camera. As might be expected, his physiological indicators showed he was under considerable stress. In general, his suit was so cumbersome that he could do little more than float awkwardly at the end of his tether and wave for the cameras. The whole event amounted to about 20 minutes exposure to the vacuum conditions, of which about 10 were outside the ship on the tether. Leonov explained later that he had some difficulties in his big suit getting back in without losing his camera, and Colonel Belyayev had to repeat the orders to get him to come in, as he not only experienced the tension of being the first to go out, but the same euphoria several American EVA astronauts displayed.

As had happened after previous Soviet flights, the claims of Leonov's EVA came under some dispute in the West. Complaints centered around analyses of the Soviet-released pictures which included not only blurred views, and the better motion pictures, but a number of sequences to fill in with simulation what would have been harder to

provide during the real event. This explains the question "Who was holding the camera for the clear shots of his emergence from the air lock?" and also some process shots taken either in a water tank or with guide wires in another view. One can dispute particular pictures, but the total evidence that EVA occurred is reasonably compelling.

While preparing for reentry after 16 orbits, the crew discovered that the automatic orientation devices necessary for retrofire were malfunctioning, so they were authorized to orbit one more time and then make a manually controlled reentry. This moved the landing site into European Russia instead of Kazakhstan, and for some reason reentry was delayed long enough to carry the ship hundreds of kilometers north into Taiga where they landed amidst pine forest. It took several hours for the recovery team to locate the ship, and about a day for ground parties to cut through the forest to reach the cosmonauts and bring them home. As wolves howled nearby, the crew kept close to their capsule for protection.

II. The Soyuz Program

A. PRECURSOR FLIGHTS TO SOYUZ

When expectations of continuance of the Voskhod program were not fulfilled, Western observers debated whether the Soviet Union had abandoned manned flight or whether they had paused in order to make much more fundamental changes in their systems. The pause was fairly long, almost 22 months, but at last on November 28, 1966 came a routinely announced Kosmos flight, 133, which had the telltale signs of low perigee, fairly circular orbit, a radio beacon frequency usually reserved for manned flights, and recovery after only two days of flight instead of the eight typical of military recoverables.

Kosmos 140 was put into a similar orbit on February 7, 1967, and again stayed up only two days. Then rumors began to build that a manned flight was coming.

B. SOYUZ FLIGHTS 1–9

1. Soyuz 1

In April 1967, after a period of two years in which the Russians did not fly any manned missions and the Americans were establishing one record after another in their Gemini program, rumors of the most ambitious and spectacular manned flight operation became very strong in Moscow. Thus on April 23, 1967, Col. Vladimir Komarov, the first Russian to make a second trip into orbit, was launched into space by an A–2 vehicle in a payload which probably weighed about 6,570 kg.

Soviet reports indicated that all was going according to plan, their standard description, but one could infer the opposite when his ship was ordered to land after only one day in orbit with nothing spectacular to show for the flight. It is possible that another craft was supposed to be launched and a link-up obtained, although the precursor flights, Kosmos 133 and 140, were only two day flights and a longer flight would probably have been in order if docking was the goal. The rumors of a spectacular flight could have alluded to the entire Soyuz program, not this particular mission.

Komarov accomplished retrofire on his 18th orbit, an unusual step since when recovery is planned after one day it normally occurs after

16 or 17 orbits in order to bring the ship down in the prime recovery area in Kazakhstan. However, the 51.8° inclination of the flight also brought the 18th orbit to the regular recovery area. One gathers that to this point the pilot was in no immediate danger, since Soviet spacecraft are equipped with backup safety features. (Data made available during ASTP raises some safety questions.) Retrofire and passage through the upper atmosphere where radio blackout occurs is said to have passed routinely. But what happened after that is still unclear, for in the last few kilometers of descent, the parachute system which should have given Komarov a steady ride down to the surface for a final rocket soft landing failed, remaining furled and twisted with its lines so that the ship, and pilot, were destroyed in the hard impact.

Speculation as to what happened has included whether the aerodynamics of the flight had not been tested enough, since Soyuz was a different shape from its predecessors, to the rumor that while the ship was on the pad water seeped into the parachute compartment, interfering with the system's effectiveness. This seems unlikely, since all manned payloads have a shroud until they are outside most of the atmosphere, a protective environmental blanket while on the pad, and a large escape rocket assembly on top of the Soyuz class ships which should cover the parachute compartment.

Komarov's death was, of course, a great shock to the Russians, especially since only three months earlier the United States had lost the crew of Apollo 1 in a pad fire as they were running tests a few days prior to launch. Although the Soviet Union sent a message of sympathy, it was coupled with claims that the U.S. accident was a direct outgrowth of a reckless race to be first on the Moon and the greed of U.S. private enterprise willing to cut corners in safety and quality, even for manned flights. The statements implied that such considerations were nonexistent in the Soviet Union.

Although the fraility of human planning was revealed in the Apollo fire, which only in retrospect became so clearly deficient in design, the Soyuz 1 accident showed that accidents are not tied to economic or political systems, but to design, quality control, and sometimes simply lack of knowledge or human error.

Just as the American manned space effort was delayed for almost two years for investigations into the Apollo fire, the Russian manned program waited for 18 months before seeing another launch.

2. Kosmos 186 and 188

Just in time to highlight the 50th anniversary of the Soviet State in early November 1967, the Soviet Union conducted a double space operation with unmanned Soyuz prototypes. On October 27, 1967 Kosmos 186 was put into a low circular orbit for a period of four days. While Kosmos 186 waited in orbit, Kosmos 188 was launched on October 30 for a three-day flight. This was a direct ascent, first orbit rendezvous launch, which brought it within about 24 km of Kosmos 186. At this point the ships were programmed to conduct a completely automatic close rendezvous and docking on the side of the world away from Soviet territory, later passing over the U.S.S.R. in docked configuration.

When the seeking devices on both ships found each other, they were oriented into a head-on position and Kosmos 186 became the active

vessel, moving in until its docking probe was inserted into the receptacle of the other ship. Further automatic devices then completed a tight lock and made electrical connections so the two ships could operate as a single unit. They remained docked for 3.5 hours and after 2.5 orbits accomplished an equally automatic undocking over Soviet territory and resumed separate flights. A day later Kosmos 186 made a soft landing in the usual recovery zone and two days after that Kosmos 188 was recovered in a similar fashion.

This succesful operation showed that modifications had been made in Soyuz and drawings were finally released to the public showing the approximate appearance of the two ships as they approached each other. (One must say approximately because it later developed that some essential elements of the design had been airbrushed out, and it was many months before the actual shapes became apparent.) The first drawings showed a cigar-shaped craft with docking collar and probe or receptable at the forward end, and a propulsion unit at the other. Special acquisition and distance-measuring radars extended out from the ships on hinged lattice-structure arms. Most distinctive were the solar panels which unfold after orbit is attained and look like rectangular gull wings. The Russians developed these as a source of electricity as opposed to the American fuel cells.

3. Kosmos 212 and 213

On April 14 and 15, 1968, Kosmos 212 and 213 respectively were placed in a low circular orbit, each remaining for five days. Prior to the second launch, Kosmos 212 made slight orbital corrections which brought it very nearly over the launch site to simplify rendezvous. At the time the carrier rocket was separated from the Kosmos 213 payload, the controllers on Earth had accomplished a first orbit, direct ascent rendezvous which brought Kosmos 213 to within 5 km of Kosmos 212, and the velocity difference was only about 108 km per hour. After mutual radar search and lock-on, Kosmos 212 became the active partner and completed the exercise. Main propulsion which could be turned on and off was used for most of the closing, but when the ships were within a few hundred meters of each other, low thrust propulsion was employed, and the difference in their relative speed was between 0.5 and 1 km per hour. This time, by Soviet claim, docking was conducted over the Soviet Union (this is hard to reconcile with other Soviet data), but the follow-up rigid mechanical lock and the interlinking of electrical connections occurred some minutes later over the Pacific Ocean, 47 minutes after launch. On the next pass over the Soviet Union external television cameras on the ships showed how they looked.

The ships remained linked together for 3 hours 50 minutes, and then undocked on radio command over Soviet territory. Each ship then made further maneuvers repeatedly to continue group flight, but at a distance sufficient to avoid mutual interference.

4. Kosmos 238

On August 28, 1968, still another flight was made which had the orbital path and radio frequency characteristics of a manned precursor. It was never commented on by the Russians after the initial launch announcement under the Kosmos cover name, but after four days in orbit it was called down. Apparently it represented a final check of on-board systems as a step in man-rating.

5. Soyuz 2

Soyuz 2 was launched without any immediate announcement on October 25, 1968 and was placed in the typical low parking orbit of the other Kosmos precursor flights. It remained in orbit for three days and was the target for the manned flight which followed. Despite its unmanned status, the mission was given a Soyuz name instead of the Kosmos designation for unknown reasons.

6. Soyuz 3

On October 26, 1968, 18 months after the ill-fated flight of Komarov, the Soviet Union launched Soyuz 3 carrying Colonel Georgiy Beregovoy. After achieving a co-orbit with Soyuz 2, the ship made an automatic approach to within 200 meters. After that, the pilot took over manual controls and made repeated approaches toward Soyuz 2, coming very close and reducing the differences in velocity to less than one kilometer per hour. For some unknown reason he was unable to accomplish actual docking although this was clearly his objective.[1] Television coverage of these operations was provided by external cameras.

More details about the ship itself emerged, revealing that there were two passenger compartments, a fact less clear from earlier drawings. Beregovoy slept in a separate work compartment, while piloting was done in the command module, which was also the recoverable part of the ship. The total volume of the two compartments, which were connected by an air lock, was about 9 cubic meters. The ship had a 30-day stay time capability and some versions could fly up to 1,300 km above the Earth. The descent portion had special aerodynamic qualities which permitted precise landings at pre-selected points, and the lift cut the G-load to between 3 and 4 G's compared with 8 to 10 G's for a ballistic reentry, although the latter could still be used in an emergency to save time.

Retrofire was provided from a 400-kilogram-thrust liquid rocket engine with a completely duplicate engine in reserve. If both failed, normally the residual fuel of the orientation steering rockets would be sufficient to return a ship from orbit. On reentering, a drogue parachute was deployed at 9 km, followed by the opening of the main parachute, with a second parachute in reserve. Just before final touchdown, at a height of about one meter, a gunpowder rocket was fired as a final brake to soften landing.

During his four day flight, Beregovoy monitored the flight systems, gathered geophysical data, and took pictures of the Earth's surface for resource studies. Except for the strong implication (although explicitly denied) that docking was intended and failed, the flight was a good proving effort for the Soyuz hardware. At a much later date, a specific weight of 6,575 kg was filed for the ship.

7. Soyuz 4 and 5

Soyuz 4 was launched on January 14, 1969, a novel launch time for the Russians since until now they had avoided the winter season when either an aborted launch or off-course landing might mean a delay in crew rescue under severe weather conditions. However, not only did the ship have an enhanced water-landing capability so a sea landing in

[1] Moscow Radio October 28, 1968, 0200 GMT.

the tropics could occur if necessary, but the Russians were by now fully confident of their systems. Put into the typical low Soyuz orbit, the ship was piloted by Col. Vladimir Shatalov. The next day Soyuz 5 was launched with a three man crew: Lt. Col. Boris Volynov, commander; Master of Technical Sciences Aleksey Yeliseyev, flight engineer; and Lt. Col. Yevgeniy Khrunov, research engineer.

After a number of orbital corrections by both ships, the docking exercise began on Soyuz 5's 18th orbit, and Soyuz 4's 34th. The automatic system brought the ships to within 100 meters of each other whereupon Shatalov completed a manual approach. On the 35th orbit of Soyuz 5, Khrunov and Yeliseyev donned pressure suits and self-contained life support systems, entered the orbital work compartment, sealed the inner hatch, then opened their outer hatch, and transferred to Soyuz 4, floating and using handrails on the outside of the crafts for assistance. Both men were outside for about an hour, with television cameras recording the entire affair and constant radio communications maintained. Khrunov made the transfer over South America while Yeliseyev did so over the Soviet Union. In turn, the orbital work compartment of Soyuz 4 served as an airlock.

The ships remained docked for 4 hours 35 minutes. Soyuz 4 returned to Earth after three days, now carrying a crew of three instead of one, and Soyuz 5 landed after three days with only one man aboard instead of three. Soyuz 4 and 5 were later registered as weighing 6,625 kg and 6,585 kg respectively, for a total weight of 13,210 kg. As a result of maneuvers and usage of other expendables, their combined mass at the time of docking is estimated as being 286 kg lighter, or 12,924 kg.

The combined ships have always been hailed in the Soviet press as the world's first space station in which a total of four men were housed. Although the combination can be considered a station in that a fair amount of working space was provided by the orbital work compartments, the general view of a space station suggests a longer duration of usefulness and no need for EVA to go from one work compartment to another. The ships' orbit was low enough that it would have decayed in about ten days, and the main life support systems, solar panels, and orbital adjustment rockets were in the after-service modules, separated from the orbital compartment by the command modules. Thus the "station" could not have been left behind in orbit for visits from other crews.

New pictures were released showing the true shape of Soyuz: a spherical work cabin at the front end separated by a hatch from a bell-shaped command module with its slightly convex reentry shield facing aft, and at the rear, the cylindrical service and propulsion module with its two solar panels.

8. Soyuz 6, 7 and 8

Launched on three successive days, Soyuz 6, 7 and 8 were to perform group flight with orbital assembly the prime mission. Soyuz 7 and 8 were meant to dock with each other for joint experiments, but Soyuz 6 was almost incidental to the mission since it could have flown any time after Soyuz 4 and 5. Reasons why the Russians might have waited include the possibility that other projects had a higher priority for the tracking system and data central during the middle months of the year. Second, putting it up in conjunction with the next two

Soyuz flights would reduce the cost of maintaining ocean tracking ships on station in all parts of the world. Third, by having three manned ships up at one time, the abilities of the computers and operations people to handle a much more complex data management system was given a good test. Fourth, having seven men up at once has a certain appeal as a portent of things to come.

The flights were terminated after five days each. There were rumors in the West that other ships were to have been launched and that the flight was to have run much longer. But it should be noted that before the first launch occurred, Moscow unofficial reports said that three ships would be involved with at least six cosmonauts, for a total period of one week.[2]

a. Soyuz 6.—Launched on October 11, 1969, this flight was piloted by Lt. Col. Georgiy Shonin and flight engineer Valeriy Kubasov. It not only tested the Soyuz systems, but also contributed to gathering Earth resources data. Its most important and significant experiment, though, dealt with alternate methods for welding in the high vacuum and weightlessness of outer space.

The Russians consider welding as necessary in future space operations if very large permanent stations are to be assembled and if such stations are also to be used for the assembly of expeditions to visit the planets. Thus they built into the Soyuz 6 work space remote handling equipment to conduct welding experiments, after first opening the cabin to vacuum conditions. The welding unit. Vulkan, was controlled remotely by electric cable. They tested three methods: a low pressure compressed arc, an electron beam, and arc welding with a consumable electrode. Only the electron beam experiment was reported as categorically successful.

b. Soyuz 7.—This launch occurred on October 12 with a crew of Lt. Col. Anatoliy Filipchenko, Flight Engineer Vladislav Volkov, and Research Engineer Viktor Gorbatko. The ship carried docking equipment and was meant as the passive target for Soyuz 8. Aside from group flight activities, its principal task was Earth resources and related research.

c. Soyuz 8.—Launched the day after Soyuz 7, the flight was commanded by Col. Vladimir Shatalov, accompanied by Flight Engineer Aleksey Yeliseyev, both veterans of the Soyuz 4/5 operation. Designed as the active partner in docking with the larger crew in Soyuz 7,[3] many maneuvers were made between the two ships but docking was never accomplished. Although Soviet accounts vary from outright denial of docking plans to evasion on this point, it seems likly that a pair of ships equipped with docking gear instead of other experiments are meant to dock. What is unclear is whether automatic docking routines would have been successful as in the double Kosmos missions, or whether a mechanical problem precluded either automatic or manual docking.

9. Soyuz 9

Soyuz 9 was launched on June 1, 1970 from Tyuratam with Col. Andriyan Nikolayev as pilot and Vitaliy Sevastyanov as flight en-

[2] First reported by Paris AFP on Oct. 9, 1969, naming three ships and docking; then reported on Oct. 10 by Moscow UPI as imminent; then stated on Oct. 13 by the Yugoslav agency Tanyug as being for one week. All these rumors were confirmed by events.

[3] TASS, October 15, 1969, 1846 GMT.

gineer. This ship lacked rendezvous and docking systems and was sent on a solo flight to test for a longer period of time than other flights, the capacity of both the hardware and the human crew. On the fifth orbit the ship was raised from its initial orbit to protect its orbital life from early decay. On the 17th orbit, the perigee was raised again to establish a still more durable circular orbit.

Medical-biological research effects of long term exposure to space conditions were probably the primary mission of this flight, but it also afforded a good opportunity to enhance capabilities related to Earth resources observation. These concentrated on both visual observation and photographing geological and geographic objects, weather formations, water surfaces, snow and ice cover, and conducting other ground studies.

Onboard television cameras gave the ground controllers and Soviet public live coverage of activities on the ship during some orbital passes. The crew found the ship comfortable, and slept for eight hours at a stretch on couches in the work compartment, using sleeping bags. A stove provided hot meals of a wide range of conventional foods, and shaving was accomplished with both the shaving cream method and a dry electric razor. Lacking a shower they resorted to twice-daily rubdowns. A vacuum cleaner was used to maximize the cleanliness of their living spaces.

As far as the ship itself was concerned, the Russians claimed that the 14 square meters of solar panels with chemical buffer batteries were more reliable than the American fuel cells used in Gemini and Apollo. They also felt that their use of two cabins made it possible to provide a work and sleep area with no threat of clutter and interference to the flight and recovery operations conducted in the command module. Also, the pilot would have no need to put on a pressure suit if his companion(s) conducted EVA exercises through a hatch from the work module.

On the 14th day of flight, the orbit was lowered as a precaution for later recovery, particularly if retrofire should not be successful. But retrofire occurred as expected, and the command module separated from the work and service compartments for landing on June 19 in Kazakhstan. The crew was immediately picked up and although they were in good condition, after 18 days in space they had a harder time adjusting to full Earth weight than American crews who had stayed up for 14 days. The men were taken to a new quarantine laboratory whose description sounded very much like the Houston lunar receiving laboratory. In the later Moscow celebrations, Nikolayev was promoted to Major General.

The following experiments were conducted:

Medical.—The crew made measurements of their condition before and after exercise, noting arterial pressure, pulse and respiration. They checked the contrast sensitivity of their eyes and made many tests of their vestibulary sensitivity in weightlessness. Samples of air breathed before and after exercising was collected in plastic bags for analysis on Earth, with expectations that the ratio of carbon dioxide and oxygen would give a measure of energy expenditure. The dynamics of pain sensitivity were checked and maximum hand strength tested with a dynamometer.

During the 13th day of flight, a test of Sevastyanov's mental capabilities was made by exposing him to a simulated set of commands

which had been preprogrammed into the on-board computer, as a comparison with his corresponding capabilities earlier in the flight.

Other Biological.—Experiments were performed relating to the micro and macro genesis of flowering plants, the division of cells of chlorella, the propagation of bacterial cultures in liquid media, and the propagation and development of insects.

Earth Resources.—On the fifth day the crew watched a large tropical storm in the Indian Ocean and observed surf on a continental shore. The next day they observed forest fires in Africa near Lake Chad.

They used both black and white and multispectral color film to photograph the Earth's surface which was expected to throw light on problems of identification of different kinds of Earth rock and soil, the moisture content of glaciers, the location of schools of fish, and estimation of timber reserves.

The crew also made studies of aerosol particles in the atmosphere by observing twilight glow.

Navigation.—Astronavigation was practiced by locking onto Vega or Canopus and then using a sextant to measure its relation to the Earth horizon. Spectrographic measurements of the horizon were taken to define it better for navigation purposes. Arcturus and Deneb were later added as sighting targets for navigation tests.

On the 4th day, using on-board navigation and measuring equipment, the orbital elements were refined to three decimal places—that is, to an exact number of meters for apogee and perigee, to an exact number of thousandths of a minute for period, and to the exact number of thousandths of a degree in inclination.

Astrophysical.—In addition to observing celestial bodies, the cosmonauts made photographic studies of the Moon.

C. FURTHER TESTS: KOSMOS 379, 382, 398 AND 434

A new series of tests ran from late 1970 to mid-1971. These were as follows:

TABLE 3-1.—FLIGHT PARAMETERS OF KOSMOS 379, 382, 398 AND 434

[Altitudes in kilometers]

Name	Date	Comments	Apogee	Perigee	Inclinatio
Kosmos 379	Nov. 24, 1970	Original Announcement	253	198	51.6
	Nov. 25	After Maneuver	1, 210	190	51.6
	Nov. 30	After Maneuver	14, 035	175	51.7
Kosmos 382	Dec. 2	Original Announcement	5, 040	320	51.6
	Dec. 7	After Maneuver	5, 072	1, 615	51.6
	Dec. 8	After Maneuver	5, 082	2, 577	55.9
Kosmos 398	Feb. 26, 1971	Original Announcement	276	196	51.6
	Feb. 27	After Maneuver	1, 188	186	51.6
	Feb. 28	After Maneuver	10, 903	203	51.6
Kosmos 434	Aug. 12	Original Announcement	285	197	51.6
	Aug. 16	After Maneuver	1, 328	189	51.6
	Aug. 27	After Maneuver	11, 804	186	51.6

SOURCES: TASS announcements and RAE registers

Clearly three of the flights fit one pattern, while the fourth (Kosmos 382) is unique. Although all four used an orbital platform, the three similar ones abandoned their rocket stage at the low initial orbit, abandoned the platform at the intermediate orbit, and the payload then provided its own propulsion to the highest orbit. The Royal Aircraft

Establishment (RAE) report suggested, however, that Kosmos 382 used a double burn of the launch vehicle rocket stage, for their register lists it as first appearing in the initial orbit and then shifting to the intermediate, where the platform was released. The RAE apparently misinterpreted events, though, or one would have to assume the rocket stage actually made a separate maneuver equal to that of the launch platform. They probably relied on poor information from NORAD which the latter organization did not correct or qualify. Since this is contradictory, the object reported by RAE close to the initial orbit of the payload must not have been the same rocket casing listed at the intermediate orbit.

The nature of the initial orbits of the three similar flights was very similar to a Soyuz orbit, and indeed the signal formats and frequencies used also resembled Soyuz, so an A–2 launch vehicle was used. But Soyuz class ships have repeatedly been listed by the Russians as having a maximum altitude of 1,300 km. The use of an orbital launch platform like a lunar or interplanetary flight and the further climb with onboard propulsion to more than 10,000 km is clearly beyond the Soyuz capability. This, then, was the first use of the A–2–m vehicle, a much more maneuverable version of the A–2.

Kosmos 382, though, differed from the other flights not only because the perigee was raised instead of the apogee, but a very substantial plane change was accomplished in the final maneuver. If this payload was similar to that of the other three, then only a D class vehicle could have been used to make maneuvers of such magnitude, and that apparently was a D–1–m.

Mr. G. E. Perry of the Kettering Grammar School in England calculated the delta V's involved in Kosmos 379 and found a very close match to what might be expected for lunar orbit insertion and for trans-Earth ejection.[4] He concluded that all four flights involved testing of a Soviet equivalent of the American SPS engine used for the Apollo command service module on lunar flights. The assignment of the three similar flights to the Earth-orbit category in the 1966–70 edition of this report resulted in some criticism. That all four were Moon precursors is a logical explanation, but knowing the limitations of the A–2 vehicle and keeping to a very conservative analysis, the original designation of Kosmos 379, 398 and 434 as Earth-orbit related and Kosmos 382 as part of the lunar program stands until such time as an overt program clarifies the situation.

D. THE SPACE STATION ERA

1. *Soyuz 10 and 11 with Salyut 1*

By the earlier criteria listed under Soyuz 4 and 5 for a space station, the world's first such station was launched by the Soviet Union in 1971. Two missions, Soyuz 10 and 11, were sent to work with the station and it remained in orbit for about six months.

a. Salyut 1.—Very early on April 19, 1971, the unmanned space station Salyut 1 was launched from Tyuratam by a D–1 vehicle into a 222 x 200 km orbit inclined at 51.6°. Initial announcements were vague, as usual, stating the purpose of the mission as a test of elements of the

[4] Perry, G. E. Flight International, London, December 10, 1970, p. 923.

systems of the space station, and to conduct scientific research and experiments on board the craft. The station was described simply as multipurpose and complex, for carrying out diverse plans.

It was not until the launch of Soyuz 11 that more details were released about Salyut, and it was initially described as 20 meters long with a maximum diameter of 4 meters. Since the original announcement, however, the length has alternately been given at 21.4 meters [5] and 23 meters [6] with a maximum diameter of 4.15 meters.[7] Later in this chapter one will see that Salyut 3 was announced as being 21 meters long, and Salyut 4 as 23 meters. It seems unlikely, due to technical and development cost constraints, that each space station would be a different length, so it is suspected that external attachments such as radio transponders are sometimes counted as part of the overall length and other times they are not.

Salyut is made of several compartments and the measurements for each of these seem uniform from one version to the next. The compartment that serves as a transfer tunnel from the ferry craft to the space station is 3 meters long and 2 meters in diameter. The main habitable portion is comprised of three sections: The small cylinder 3.8 meters long and 2.9 meters in diameter; the large cylinder 4.1 meters long and 4.15 meters in diameter; and a cone connecting the two which is 1.2 meters long. An unpressurized service module completes the station, and it is 2.17 meters long and 2.2 meters in diameter.

The internal area of the space station is consistently listed as 100 cubic meters, and the weight of the combined Salyut/Soyuz system is consistently "over 25 metric tons". Since Soyuz is about 6,575 kg, Salyut would be in excess of 18,425 kg (estimates usually place this weight at 18,600 to 18,900 kg).

Television views showed a considerable amount of space with big chairs and several control panels. Later it was revealed there were eight chairs, seven at work stations. Altogether there were 20 portholes, some unobstructed by instruments to give a good view of the Earth and outer space.

Externally, there were two double sets of solar cell panels, placed at opposite ends, extending like wings from the smaller diameter compartments in much the same manner as the panels on the Soyuz. Also externally were the heat regulation system's radiators, the orientation and control devices. Some of the scientific instrumentation was internal, some external.

Because of the low orbit of Salyut during the time it served as Soyuz 10's rendezvous target, the station would have decayed into the atmosphere around May 3. Therefore, after Soyuz 10 had completed its mission, the onboard propulsion systems were fired to raise the orbit by about 50 km. At least twice during May the orbit was raised even more to offset orbital decay.

This procedure was also followed after the Soyuz 11 visit, this time to test the longevity of the station and to keep open the option to send another crew. But finally on October 11, its engines were fired for the last time to insure decay over the Pacific Ocean. Pravda reported on October 26, 1971 that the Salyut tasks were solved in 75 percent of

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[5] "Saliout" devoile pour la premiere fois. Air et Cosmos, Paris, May 31, 1975.
[6] Salyut na Orbite, Moscow: Mashinostroyeniye, 1973, page 8.
[7] Les Stations Orbitales "Saliout", Moscow: Mashinostroyeniye, 1975, page 14.

cases by optical means, in 20 percent by radio-technical means, and the small balance by magneto-metrical, gravitational, and other studies. Often synoptic readings were taken in both the visible and invisible parts of the electromagnetic spectrum.

b. Soyuz 10.—At 2354 GMT on April 22, 1971, Soyuz 10 was launched by an A–2 vehicle into a 246 x 208 km orbit inclined at 51.6°. The crew consisted of Col. Vladimir Shatalov, Flight Engineer Aleksey Yeliseyev, and Nikolay Rukavishnikov, described as responsible for operation of systems in the Salyut station.

Instead of making a fairly direct ascent to rendezvous with Salyut, almost 24 hours passed before this was accomplished. Salyut was maneuvered four times; Soyuz 10 made 3 principal maneuvers. One of these came 13 hours 35 minutes into the flight on instructions from the new, large tracking ship, *Akademik Sergey Korolev*, stationed in the Atlantic.

Automatic devices did the actual work of rendezvous until the two craft were 180 meters apart. Shatalov then took over manual control, commenting later that due to the difference in size, Soyuz seemed like a train entering a railway terminal. The crew said they were not able to see Salyut until it was only 15 km away, and then they used an optical device to see it. They described the station as very impressive, and painted in more brilliant colors than they had noticed while it was on Earth.

The docking was apparently quite nerve-wracking, with Shatalov steering while his colleagues monitored various instruments on the status of systems. Soviet commentary noted that the problems of docking with a large mass, unmanned, nonmaneuvering station were quite different from the docking of two Soyuz ships, each able to adjust its position. The Russians reported that new telemetry, rendezvous and docking equipment was used for this mission.

The ships remained docked for about 5.5 hours. Television cameras mounted externally on both ships had watched the procedures of approach, docking, and separation. After the undocking, Soyuz 10 flew all around the station to take a variety of pictures, and then preparations were made for return to Earth. Retrorockets were fired at the first opportunity which would permit return in the normal recovery area, and reentry occurred as expected. The flight lasted just short of two days, and the predawn landing near Karaganda was another first in the Soviet program, since all other landings had taken place in daylight.

The early return of Soyuz 10 and the failure of the crew to transfer into Salyut suggested that the mission had not accomplished all its objectives. The Russians said that although the flight had been short, it had been scheduled to a very tight degree for the research and testing tasks which were successfully accomplished. It seems reasonable to accept the statement that the mission achieved its primary objectives of exercising the new telemetry, docking and control systems, and to recover the men, with further unmanned experiments continuing with the Salyut. But it also seems likely that the total mission fell short of its engineering capabilities and Soviet hopes. Some Western observers read significance into the report that the crew was met by a smaller delegation of officials than other returning cosmonauts, although the traditional welcome was accorded the three men in the formal reception in the hall of the Great Kremlin Palace.

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Possible signs of trouble in the mission include:

(1) The failure of the crew to transfer into the station after a successful mechanical docking seems surprising, especially because Rukavishnikov was a specialist in the Salyut systems. Either the hatches and air locks were not functioning properly, or there was some threat of trouble which might require a quick disconnect and return to Earth.

(2) The early return to Earth at the first opportunity suggested either trouble in Soyuz 10, or such dependence upon equipment, consumables, and systems of Salyut that when these were found to be unavailable, there was no point in prolonging the mission.

(3) When all previous Soyuz flights are plotted on a graph to compare hour of launch with number of days in flight until recovery, a very regular relationship is revealed. On this basis of estimation, the pre-dawn launch of Soyuz 10 seemed to suggest a 30-day flight, and yet the flight terminated after only 32 orbits (2 days), with a pre-dawn landing.[8]

c. Soyuz 11.—On June 6, 1971 at 0455 GMT, Soyuz 11 (code named Yantar or Amber) was launched with a crew consisting of Lt. Col. Georgiy Dobrovolskiy, Flight Engineer Vladislav Volkov, and Salyut Test Engineer Viktor Patsayev.

The first day of flight passed routinely, with appropriate maneuvers to effect a rendezvous until Soyuz 11 was 6–7 km from Salyut, about 0426 GMT June 7. At 100 meters Dobrovolskiy took manual control. The complicated process of docking, which wasn't completed until 0745 GMT, required: initial engagement (soft-dock), making the connection mechanically rigid (hard-dock), engaging various electrical and hydraulic links, and a thorough process of establishing air-tight seals (hermetic sealing). After pressure was equalized between the two ships, the locks were opened and Patsayev transferred into the space station, soon followed by Volkov. After they turned on the systems and switched command functions of the combined craft to the central control panel in Salyut, Dobrovolskiy joined them.

After crew transfer, the Russians announced their mission as:

(1) To check and test the design, units, onboard systems and equipment of the orbital piloted station;

(2) To try out the methods and autonomous means of the station's orientation and navigation as well as the systems of controlling the space complex while maneuvering in orbit;

(3) To study geological-geographical objects on the Earth's surface, atmospheric formations, the snow and ice cover of the Earth with the aim of developing methods of using these data in the solution of economic tasks;

(4) To study physical characteristics, processes and phenomena in the atmosphere and outer space in various ranges of the spectrum of electromagnetic radiation;

(5) To conduct medico-biological studies to determine the possibilities of performing various jobs by the cosmonauts in the station and to study the influence of space flight factors on the human organism.

A summary of the cosmonauts' activities by day is presented in Table 3–2, which provides both a picture of what happened each day on this

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[8] Clark, P. S., Journal of the British Astronomical Association, London, December 1973, pp. 34–35.

mission and serves as a sample for other space station missions in this report.

In general, health monitoring and exercises for the crew were continued throughout the mission. Some monitoring was close to continuous, some was periodic, and some was supplemented with more detailed self-administered tests. Other biological specimens and a hydroponic farm for growing plants were carried and used in experiments. Work related to Earth resources and weather was extensive. Detailed astronomical work began about midway through the mission, although various radiation studies had been conducted earlier. Ship systems and instrumentation got considerable testing.

When looking at the table of daily activities, an intriguing change in the routine occurs on June 17. The Soviet press gave no reports of scientific work or television transmissions, but only mentioned "minor correction work", adding that the ship was equipped with tools, spare parts and safety devices. On June 18 the routine returned to normal, but G. E. Perry of the Kettering Grammar School in England detected telemetry transmissions on the Soyuz 11 frequency. This might have signalled that the trouble of the day before was forcing an early return, but the mission continued.

TABLE 3-2.—DAILY LOG ACTIVITIES ON SALYUT DURING THE PERIOD SOYUZ 11 WAS DOCKED TO IT

Date	Earth observations	Astronomical observations	Biology operations	Ship systems
June 7, 1971			Test on board life support systems	Dock and seal hatch connections. Hookup communications. Activate systems. Functioning normally.
June 8, 1971	Check research equipment and activate it		Test on board life support systems in different regimes. Do exercises.	Make orbital correction, then spin stabilize. TV broadcast to Earth. Functioning normally.
June 9, 1971	Make further adjustments to equipment. Measure radiation levels, micrometeorites.	Test wide-angle sights for precise orientation on Sun and planets.	Try out tension suits to simulate gravity force on muscular-skeletal system. Do other medical and biological experiments.	Make second orbit correction. Stress conservation of ship systems. Check gas atmosphere. TV broadcast to Earth. Functioning normally.
June 10, 1971	Using various lenses and filters, make reports on weather, clouds, snow, ice.		More physical exercises. Take blood samples. Check cardiovascular systems. Check bone calcium density, Check water balance. Check experiments with fruit flies, chlorella, seeds.	TV broadcast to Earth. Functioning normally.
June 11, 1971	Spectrographic measures of atmosphere, land and water surface. Measure micrometeorites.	Use gamma ray telescope to study intensity, angular distribution, energy spectrum of primary cosmic gamma radiation. Check influence of space environment on optical samples for developing extra-atmospheric telescopes.	More biological monitoring of cosmonauts, including vestibular reactions and arterial pressure.	Functioning normally in full conformance with plans.
June 12, 1971	Photograph various atmospheric formations		Check radiation safety by effective dosimetric system—values and build-up of doses by different components. Test respiration, gas exchange, energy expenditure. Test blood circulation, EKG, seismocardiogram, pulse, other cardiovascular measures.	TV broadcast to Earth. Stable communications. Functioning normally, all according to plan.
June 13, 1971	In joint tests with Meteor satellites, observe and photograph cloud cover.	Measure characteristics of cosmic radiation	Do physical exercises. Use hydroponic farm to raise Chinese cabbage, flax, and onions.	Test autonomous navigation system. Functioning normally.
June 14, 1971	Joint experiments with aircraft carrying same instruments to check spectra of reflectivity, soil characteristics. Also check cloud cover.		Continue 2 hours daily exercise. Continue automatic monitoring of medical condition by speech, cabin parameters, pulse, respiration, EKG, seismocardiogram at least twice daily.	Adjust autonomous navigation system using on-board computer. TV broadcast to Earth. Functioning normally, all according to plan.
June 15, 1971	Joint test on cloud cover with Meteor. Joint tests with aircraft on spectral characteristics of surface formations for agriculture, land improvement, geodesy, cartography.		Measure surface and deep radiation to determine relative biological effect of cosmic radiation, sorting out protons, neutrons, and gamma radiation. More cardiovascular tests.	TV broadcast to Earth. Crew feeling well.
June 16, 1971	Radio frequency mass spectrometer used to investigate composition of upper atmosphere. Photometry of light effects. Distribution of charged particles—ions, electrons, in orbit. Study of high frequency electron resonance on antenna performance.		Crew equipped with flight suits, exercise suits, "Penguin" suits to put stress on skeleton and muscles like Earth gravity, and one other kind of stress suit.	Good results in testing manual and automatic ship control, using optic sighters, plotters, astronomical reference points, new ion orientation. Functioning well, crew feels well.

June 17, 1971			Day of rest, performing physical exercises, mutual medical exams.	The crew continues to fulfill the program. [Soviet press: We hear report of minor correction work. Answer: Ship carries tools to open instrument panels, spare parts, safety devices.]
June 18, 1971		Experiments begin with Orion astrophysical observatory on board, with checkout of equipment. To study spectral character of stars in short wavelengths not visible from Earth.	Attention to farm of kale, flax, crepis. Use of exercise machines and load suits for 2½ hours.	TV broadcast to Earth. Functioning normally. [Kettering Grammar School detects Soyuz 11 frequency telemetry for some hours as if equipment switched from dormant to powered up state for recovery.]
June 19, 1971	Optical studies of Earth day and twilight horizons, with spectrograph. Study distribution of aerosol particles.		Investigation of cardiovascular system using functional loads. Study visual functions of spatial perception and color sensitivity. Measure bone calcium density.	Use solar orientation instrument to check accuracy of ship gyros for extended period. TV broadcast to Earth. Functioning normally.
June 20, 1971	Sent weather reports		Day of rest	TV broadcast to Earth. Functioning normally.
June 21, 1971	Investigation of polarization of solar light reflected from Earth.	Orion experiments to obtain spectrograms of UV radiation from Alpha Lirae and Alpha Zeta of Ophiuchus, using both the external telescope and another inside the ship looking out a porthole. Further measures of primary cosmic gamma rays.	Routine medical examinations	Reoriented ship position. Functioning according to plan.
June 22, 1971	Manual spectrograph measures of physical properties of the atmosphere, especially of twilight horizon. Cloud cover and cyclone observations.		Routine medical experiments. More work with Oazis-1 hydroponic farm.	TV broadcast to Earth. Functioning normally.
June 23, 1971	Study of brightness and contrast of Earth, photographing with wide-angle system. More Earth resources experiments.		Further studies of functions of organisms under conditions of long duration space flight.	Study of optical coatings port holes. Orientation system tested. Functioning normally.
June 24, 1971	Synchronized picture taking of Earth and stars for precision location to support geology, geodesy, and cartography, both with 3-axis stabilization and while spinning on various axes.		More biological monitoring, on 12 channels of EKG and 30 blood circulation parameters. Brain blood circulation measured. Some data stored on magnetic tape.	Manual and automatic orientation of ship tested in connection with picture taking. Functioning normally, crew feeling well.
June 25, 1971	Era equipment, multifunctional, to measure parameters of ionosphere, and electron resonance, charged particles.			Functioning normally.
June 26, 1971	Record intensity of charged particles and charge spectrum of nuclei of cosmic particles.	Measure micrometeortic conditions	More measures of radiation tissue doses. Medical checkups and physical exercises.	Functioning normally, crew feeling well.
June 27, 1971			Medical experiments, physical exercises. Crew resting in turn.	TV broadcast to Earth. Functioning normally crew feeling well.
June 28, 1971			Continued checks on cardiovascular systems with and without exercise.	Check on board systems. Functioning normally, crew feeling well. [Kettering Grammar School again detects Soyuz 11 frequency telemetry as if equipment switched from dormant to powered up state for recovery.]
June 29, 1971			Mutual medical tests	Filled out ship logs. Checked ship systems. Functioning normally, crew feeling fine, Data, specimens and films moved in Soyuz 11. Hatches sealed and crew undocked.

SOURCE: Compiled from daily TASS bulletins.

On June 29 the crew prepared for return to Earth, loading scientific specimens, films, tapes and other gear aboard Soyuz 11. The ships undocked at 1828 GMT and retrofire occurred at 2234 GMT. The normal follow-on routines of casting off the work compartment and service module were carried out prior to entering the dense atmosphere. Under its automatic systems, the ship oriented itself and steered to the intended recovery area. Radio communication with the crew came to an abrupt end at the moment of separating the work compartment, probably at 2247 GMT, even before the normal ionospheric blackout. The drogue and main parachute systems functioned, and a normal landing was made at about 2317 GMT, giving a total flight duration for the men of 570:22 hours, and 383 orbits, including 18 prior to docking, 362 docked, and 3 after undocking.

Upon reaching the capsule, the recovery team was horrified to discover the three cosmonauts dead on their couches. Although the Russians did not release information concerning the cause of death for quite some time, in 1973 U.S. negotiators for the Apollo-Soyuz Test Project pressured them into releasing the first detailed explanation.

Soyuz is equipped with two valves that open for spacecraft descent venting, the first at about 5,300 meters, the second at about 4,350 meters. One of the valves failed as the work module separated from the descent module. It appears that venting took about 40–50 seconds to reach the point where the ship's atmosphere could no longer support life. The crew became aware of the problem both because they could hear the pressure leak, and because the discharge of the air resulted in a spacecraft attitude change, causing an automatic thruster to fire to compensate. The crew tried to close the leak with a crank apparatus, but was unable to do so before losing consciousness and subsequently died of pulmonary embolisms.

The deaths dealt a major blow to the Soviet space program, which entered a slowdown even in its unmanned practical applications for many months. Only late in the year did flights begin to pick up again.

2. Kosmos 496

After the long pause in man-related activities caused by the death of the Soyuz 11 cosmonauts, the Russians launched, without announcing much more than routine parameters, Kosmos 496. This was on June 26, 1972, with an apogee of 342 km and a perigee of 195 km, at an inclination of 51.6°. The flight was recovered after six days. TASS in Moscow noted that it used the 20.008 MHz frequency common to the Soyuz. On the basis of orbital calculations from Perry in the United Kingdom, Sven Grahn in Sweden was not able to find signals on 20.008 MHz, but did discover that each time the ship reached the radio horizon of Yevpatoriya in the Crimea, the ship sent signals on 922.75 MHz, which had been used in the manned program previously. There were three carriers with high-speed commutated telemetry sidebands. The strong inference was that the Russians were testing an improved Soyuz to correct the problems of Soyuz 11, and further manned flights could be expected.

3. Salyut 2

On April 3, 1973 Salyut 2 was launched into a 260 x 215 km orbit, with a period of 89 minutes and an inclination of 51.6°. The next day

Cosmonaut Yevgeniy Khrunov announced that cosmonauts were engaged in preparations for new flights, supposedly to link up with Salyut, and on April 6 Victor Louis of the London *Evening News* reported that a Soyuz spacecraft was ready for launch. Thus when no launch followed Salyut 2, there was speculation that the Soyuz launch had failed. On two occasions the space station was in a position for rendezvous, but no launch occurred. When on April 8 Salyut 2's orbit was raised to 268 x 248 km, above an appropriate rendezvous orbit, experts concluded that whatever had delayed the Soyuz launch was more serious than originally thought. Some suggested that solar flare activity on the 4th and 5th of April prevented the launch rather than equipment failure, but when April 11 came and there was still no launch, general opinion was that either Salyut or Soyuz was having major difficulty.

Spaceflight magazine reported that Salyut 2's initial orbit was higher and more elliptical than Salyut 1's, possibly due to poor performance of the D–1 booster. Numerous fragments detected in the orbital path suggested the D–1 had exploded, although in retrospect it seems likely these early pieces of debris were no more than the routine releasing of equipment and window covers.

The real trouble came on April 14 when Salyut was reported to have undergone a "catastrophic malfunction" which ripped off the solar panels and boom-mounted rendezvous radar and radio transponder, leaving the vehicle tumbling in space without telemetry return. The craft may have separated into many pieces, some large enough to be tracked, but most were rather small and decayed quickly. Either an explosion or a misfiring thruster were blamed, although the most widely held theory was that the D–1 upper stage had exploded with its debris damaging the space station.

On April 28 TASS reported that Salyut "had concluded the programme of flight," and although the official statement said it had completed its mission, the word "successfully" (used in the most nominally successful flights) was omitted. This suggests that the Russians wrote the mission off as a failure. The main body of the station decayed through air drag on May 28, 1973, and reentered near Australia.

Noting that the telemetry transmissions from Salyut 2 were similar to those used by Soviet reconnaissance satellites, *Aviation Week and Space Technology* concluded that the mission was not a Salyut at all, but that the Russians were simply trying to mislead the Soviet press and information agencies. The manned Salyut 3 a year later, however, used the same telemetry and suggests that Salyut 2 was the first of the military Salyuts.

4. Kosmos 557

On May 11, 1973, shortly after the failure of Salyut 2, the Russians launched Kosmos 557 into a 226 x 218 km orbit inclined at 51.6° and with a period of 89.1 minutes. Speculation abounded as to its purpose, since virtually no information was reported in the Soviet press. Its telemetry resembled Salyut 1, typical of the manned programs, rather than Salyut 2, typical of the unmanned military reconnaissance program. (It was not until a year later that the discovery was made that these military frequencies could be used for a manned station dedicated to military uses.)

Western experts thought there was a good chance that this was another Salyut, possibly of a different design, that failed so early in

its mission that it was listed as a Kosmos. Tracking ships deployed for the expected manned flights to Salyut 2 were reported heading back for their home ports "before Cosmos 557 decayed" [9] during the week of May 21. Whether they realized early on that no manned missions would be sent up, or whether there was no intention of sending men to it is unclear. However, no unmanned tests of Salyut stations had been conducted previously, if for no other reason than cost, so if one assumes Kosmos 557 was a Salyut, one can conclude that manned flights to it were planned, but that the station failed.

Other theories did prevail about the nature of Kosmos 557, though. Thomas O'Toole of the Washington *Post* reported it as an unmanned Soyuz sent to investigate and photograph the damaged Salyut 2, stating that its orbit was "almost identical to the Salyut orbit." [10] *Aviation Week and Space Technology*, while agreeing that it was an unmanned Soyuz, said that the two craft were too far apart for it to be an inspection mission, that there was "no way of Cosmos 557 approaching Salyut 2 without major orbital change." [11] (The difference in interpretations can probably be explained by noting that the NORAD data cited by both sources did give similar orbital elements for the two craft, but they were in different planes.)

With the passage of time and the experience with 1974 Salyut flights, it is now reasonably safe to conclude Salyut 2 and Kosmos 557 were parts of parallel but different space station programs, one military and one civilian.

5. Kosmos 573

After the failures of Salyut 2 and Kosmos 557 to operate for extended periods and to be visited by manned Soyuz, the Russians did send up another unmanned test craft. This was Kosmos 573, launched on June 15, 1973, almost a year after Kosmos 496, and flying in a very similar orbit. TASS, Moscow, announced it as having an apogee of 329.2 km, a perigee of 196.2 km, and an inclination of 51.6°. Again, they announced that it used the 20.008 MHz frequency common to man-related flights. This time the ship stayed up only two days, the pattern Soyuz 12 was to follow.

6. Soyuz 12

Soyuz 12 (Ural) was the first manned flight by the Soviet Union after the tragic deaths of the Soyuz 11 crew in 1971. The Russians delayed their manned program for two years to check systems and spacecraft design to ensure the incident would not occur again. Soyuz 12 was primarily a test of the new designs, including introduction of a new launch escape rocket, so the only experiment scheduled was Earth photography.

Launched into an initial orbit of 249 x 194 km at 1218 GMT on September 27, 1973, the ship was piloted by Lt. Col. Vasiliy Lazarev and Flight Engineer Oleg Makarov. It was inclined at 51.6° and had a period of 88.6 minutes. In a test of the control systems, the orbit was changed to 345 x 326 km, 91 minutes on the second day of flight. Sven Grahn suggested that this forecast the flying of a Salyut at higher

[9] Cosmos 557 decay. Aviation Week and Space Technology, May 28, 1973 : 25.
[10] O'Toole, Thomas. Craft Sent to Inspect Crippled Salyut. Washington Post, May 15, 1973 : A16.
[11] Soviets Try to Salvage Salyut Mission With Unmanned Vehicle. Aviation Week and Space Technology, May 21, 1973 : 16.

orbit, and his prediction was confirmed by the placement of Salyut 4 in late 1974.

Both days were devoted to checking onboard systems and photographing the Earth in various spectra, using a nine-objective camera. As the spacecraft photographed a region of the planet, airplanes simultaneously took pictures of the same area for comparison purposes to discover what distortions were introduced by the atmosphere.

Soyuz 12 landed September 29, 1973 at 1134 GMT, 400 km southwest of Karaganda, Kazakhstan. To be on the safe side, the cosmonauts wore pressure suits during reentry, as they have for all missions following Soyuz 11.

7. Kosmos 613

On November 30, 1973, Kosmos 613 was sent to a 295 x 195 km orbit inclined at 51.6°. No purpose was given beyond the routine, but Western observers noted it seemed like a Soyuz. Without announcement, the orbit was raised on December 5 to 396 x 255 km, still at 51.6° inclination. Signals were found on 922.75 MHz, typical of man-related flights. On reaching the higher orbit, little was heard from it, and it appeared to be in powered-down condition. Then toward the end of the flight, it became electronically active again, and recovery was made after a total flight duration of 60.1 days on January 29, 1974.

With the advantage of hindsight, it now seems likely that this was a first long-duration test in powered down condition for the flight of Soyuz 18 which will be described below.

8. Soyuz 13

Soyuz 13 was launched on December 18, 1973 at 1155 GMT and code named Kavkaz (Caucasus). Primarily conceived as an orbiting astronomical observatory, the cosmonauts aboard, Major Petr Klimuk and Flight Engineer Valentin Lebedev, had undergone extensive training at the Byurakan Observatory in Armenia on the operation of the astronomical equipment on board (Orion–2). On the fifth orbit, Soyuz 13 was put into a 272 x 225 km orbit, inclination 51.6°, period 89.22 minutes.

Since the orbit was similar to that planned for the Apollo-Soyuz Test Project in 1975, some speculated that this flight was a demonstration mission. But Salyut 2 and Kosmos 557 had failed shortly before this flight and it is quite possible that the Russians decided to modify the Soyuz so that Salyut-like experiments could continue until another space station was orbited. Two modifications were made to the Soyuz ship: the addition of the Orion-2 system which was mounted outside the ship in the position of the docking assembly, and the orbital section was transformed from a place for rest and relaxation into a space laboratory.

Klimuk and Lebedev remained in space for eight days, landing on December 26 at 0850 GMT, 200 km southwest of Karaganda, Kazakhstan. Five minutes later they were outside walking around.

The main projects for the mission were: astrophysical experiments with Orion–2, research into the production of protein mass in space with Oazis–2 (both of these had predecessors on Salyut 1), experiments with higher plants, biomedical checks with the Levka apparatus, earth observation, and navigation.

Medical.—The Soviets are especially interested in blood circulation to the brain in a weightless environment (blood tends to redistribute itself towards the upper part of the body in the absence of gravity). In the Levka (Lion's Cub) experiment, the cosmonauts stretch a special expander with a force of 15 kg at a rate of 30 times per minute. The heart responds by pumping more blood, and electrodes on the cosmonauts measure the response in cerebral vessels. The response is recorded by telemetric devices.

Other Biological.—Oazis–2 consists of two interconnected cylinders for the study of regeneration. One cylinder cultivates water-oxidizing bacteria which use hydrogen from water electrolysis for growth. Oxygen is formed here and passes into the second cylinder containing urobacteria (which break down urea). The urobacteria absorb the oxygen and release carbonic acid which in turn is passed back to the first cylinder and used for synthesis of biomass. Thus the waste products of one type of bacteria are the initial material used by other bacteria to accumulate protein mass: regeneration. During Soyuz 13's flight the biomass increased 35 times. This is important for long duration spaceflights where food, air and water might be regenerated so vast quantities of these perishables need not be carried on board.

Higher plants studied during this mission were chlorella and duckweed. Chlorella absorbs carbon dioxide and returns oxygen to the air, so the Russians want to see how well it grows in space, since animals, including people, exhale carbon dioxide and need oxygen to breathe. Duckweed is interesting because in the winter it goes into hibernation and exists in the form of turions, small bodies with inhibited vital activity. In the spring the turions multiply by division and again become duckweed. The cosmonauts put turions into a vessel and added kinetin to restore the vital activity. They then added a nutrient to see how the duckweed would assimilate it.

Earth Resources.—The cosmonauts again studied natural formations on the surface of the planet as well as the atmosphere. For the former, a nine lens camera which exposes three strips of film simultaneously photographed several areas of Earth. Two of the films are sensitive to visible light, the third to infrared. Each lens has color filters so many spectra can be taken and selection can be made as to which are the most valuable for specific missions.

An RSS–2 spectrograph studied the atmosphere by photographing day and twilight horizons. This can lead to better weather knowledge and information on air pollution. In addition, the spectrograph recorded the reflection of solar radiation from natural formations on Earth.

Astrophysical.—Orion 2, unlike Orion 1, was mounted entirely on the outside of the ship and had a wide field meniscus telescope which could cover an area 20 degrees square. A canopy surrounded the telescope to protect it from temperature extremes as the ship travelled into and out of the Earth's shadow, and the optical components were made of crystalline quartz. A window in the canopy opened during observation, with exposure times ranging from 1 to 20 minutes.

Designed by Grigor Gurzadyan of Armenia, the telescope is mounted on a three-axis platform which can stabilize the system with an accuracy of 2–3 seconds of arc. This is vital for successful observation. Pointing is accomplished by positioning the spacecraft within a few

degrees of the area to be studied. The two reference stars are then found, whereupon Orion-2 itself takes over with an automatic pointing system accurate to 3–5 angular seconds. The instrument has 13 electric motors for drive. Although some of the Orion-2 system is automatic, both cosmonauts are needed for these experiments; one to orient the ship, the other to work Orion.

Also mounted on the Orion system is an instrument for studying X-ray emissions from the Sun. These studies were done on the 65th orbit. The camera has several channels and can take photographs simultaneously in several ranges of the X-ray band, and has a 70 degree field of view. Observations were carried out at the same time from Earth for comparison purposes.

During the mission, the cosmonauts made 10,000 spectrograms of more than 3,000 stars in the constellations Taurus, Orion, Gemini, Auriga and Perseus. The spectrograms were in spectral classes from 2,000–3,000 angstroms (these cannot be studied from Earth since the atmosphere absorbs emissions less than 3,000 angstroms) and the stars were of the 10th magnitude generally, although the cosmonauts were able to photograph some even of the 12th. Special sensitive film was supplied by George Low of NASA for this project.

Navigation.—Experiments were continued into autonomous navigation, specifically to determine the accuracy of control systems and the testing of new instruments for orientation using the Earth and stars.

9. Kosmos 638, 656, and 672

Kosmos 638 was launched on April 3, 1974 into a 325 x 195 km orbit inclined at 51.8°, that intended later for the Apollo-Soyuz Test Project (ASTP). It stayed up ten days before recovery. Kettering found signals on 20.008 MHz.

Kosmos 656 was launched on May 27, 1974 into 354 x 194 km orbit. This time the inclination was 51.6°, that used for ferry flights to Salyut stations. The mission lasted just two days, suggesting that it was like Kosmos 573 and Soyuz 12, probably ferry versions of Soyuz without solar panels.

Kosmos 672 was launched on August 12, 1974 into a 239 x 198 km orbit, inclined at 51.8°. The orbit was adjusted to the ASTP position, approximately, when apogee was moved to 238 km and perigee to 227 km. Later, like Kosmos 638, it was confirmed by the Russians to be an ASTP test flight.

10. Kosmos 670

Kosmos 670 is worth a special look because it differed from other unmanned Soyuz flights of the period. It was launched on August 6, 1974, into a 307 x 217 km orbit. What was unique is that the inclination was 50.6°, not used on any other flight launched by an "A" class vehicle. The flight lasted only three days before recovery. In some respects, its external flight parameters hardly distinguished it from military recoverable observation flights. The inclination was close to that which Western published rumors had predicted would be that used by the big "G" class vehicle. There was speculation that this might be the first test of a ferry vehicle to a new large space station to be put up by the G–1 at some future time. Without more information, no firm conclusions can be drawn.

11. Soyus 14 and 15 with Salyut 3

In 1974 the Soviet Union launched their second successful space station, Salyut 3, which remained in orbit for seven months. It was intended to be host to two manned crews, Soyuz 14 and 15. The first docked successfully and conducted joint experiments for 14 days, while Soyuz 15 was unable to achieve a link-up.

a. Salyut 3.—Salyut 3 was launched June 25, 1974 into an orbit 270 x 219 km, inclined at 51.6° and with a period of 89.1 minutes. This Salyut was of an improved design (details will follow) and had several characteristics about it which suggest its mission was military rather than civilian.

All four men sent to work with Salyut 3 were from the military: usually in the Soyuz program Russian crews are comprised of both military and civilian persons. On board was a 10 meter focal length high resolution camera,[12] and the Russians announced that for the first time Salyut 3 was constantly oriented toward Earth with the help of an electro-mechanical stabilization system. Although this could simply indicate Earth resources photography, as the Russians announced, the low orbital parameters of the space station and the long focal length camera with its folded optics suggest high resolution photography of a nature not needed for Earth resources work. Also, during the successful docking of Soyuz 14, the crew transmitted on the 121.75 MHz frequency normally used by Soyuz missions, but once they entered the space station the frequency was changed to 143.625 MHz (Salyut 3 itself transmitted fifteen spacecraft hardware parameters on 19.946 MHz, previously used by Salyut 2).

The Russians announced that Salyut 3 was 21 meters long (see page 188) with an internal volume of 100 cubic meters. The aggregate weight of the Salyut/Soyuz system remained at over 25 metric tons. On September 23, after hosting the crew of Soyuz 14 and then being unmanned for more then two months, a module separated from Salyut, went through a reentry procedure, and was recovered, quite likely indicating that photography had continued on board Salyut automatically.

Salyut 3 functioned for more than twice its design life, reentering the atmosphere by command over the Pacific on January 24, 1975. By December 25, 1974, after completing 2,950 revolutions around Earth (by 1500 GMT), the space station had hosted 400 scientific and technical experiments, had 8,000 control commands transmitted to it, more than 200 dynamic operations were performed, there had been 70 television and 2,500 telemetric communication sessions, 500,000 firings of the stabilization engines, and 5,000 kilowatt hours of power had been produced by the solar panel energy supply system. An atmospheric pressure of 835–850 mm Hg and a temperature of 21–22°C were maintained throughout.

Some of the changes to Salyut were:

(1) Miniaturized circuitry in control loops;

(2) A more efficient power supply and life support systems, including better thermal control. Solar panels capable of rotating 180° were substituted for the stationary kind used on Salyut 1 so the station itself

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[12] Major Redesign Marks Salyut-3. Aviation Week and Space Technology, New York, July 15, 1974: 293.

did not have to be constantly turned to face the Sun. Although there were only three panels instead of the four on Salyut 1, they were larger;

(3) A general redesign of the interior. The single, large four-meter diameter working compartment was subdivided into control, working and living sections, with a corridor along the left side of the ship, from front to back, connecting the various sections to each other and the entry tunnel. All the sections were served by the same life support system, and there were no pressure bulkheads between them.

In a scheme to make the cosmonauts' new home more familiar, the floors and ceilings were painted different colors (dark for the floors, light for the ceiling) with Velcro-like material on the floor to permit more ease in walking.

The living quarters, which occupied the narrow front portion of the space station just forward of the control compartment, had four windows. Besides being equipped with a special sofa for medical experiments, there was one fixed position and one swinging bed (coming out from the bulkhead to conserve space). There were hot and cold water sources, a table for eating, storage space for clothes, linen and entertainment gear (which included a tape recorder for music, a chess set and small library), and a shower and toilet.

b. Soyuz 14.—On July 3, 1974, at 1851 GMT, Soyuz 14 (Berkut or Golden Eagle) was launched into a 270 x 219 km orbit, inclined at 51.6°, and with a period of 89.1 minutes. Piloted by Col. Pavel Popovich and Lt. Col. Yuriy Artyukhin, the ship's mission was to dock with Salyut 3 for joint experiments. When orbit was achieved, Soyuz was 3,500 km behind Salyut. After four orbital corrections, the cosmonauts were in a position for docking, and 100 meters from the station the crew took manual control. Their speed at this point was 1 meter per second, which was reduced to 0.3 meter per second by the time the ships were 40 meters apart. Using the usual probe/drogue docking system, the ships soft docked at 2100 GMT July 4 (midnight Moscow time), followed by hard dock and pressure verification. When the crew discovered that the pressure inside their ship was slightly lower than that of the space station, they raised their pressure to match. During the docking procedure, both cosmonauts wore the pressure suits they had worn during lift-off and removed after orbital insertion. At 0130 GMT July 5, Flight Engineer Artyukhin entered the Salyut, turned on the lights, and checked the life support systems.

Soyuz 14 differed from other manned Soyuzes in that there were no solar panels. Intended only as a ferry craft to take crews back and forth to the space station, internal battery power was considered sufficient for the short time it would be in solo flight, and removal of the panels created a more maneuverable ship. A porthole below the control panel between the two crew members allowed a clear view of the docking approach (although a television image was also provided on the control panel) and manual control of the ship was provided by two handles resembling automobile gear shifts (although much smaller). The left stick controlled the up, down, left, right, forward and backward motions, while the right controlled rolls along the main axis.

Two very interesting aspects of the flight surfaced in Russian news reports. First was Vladimir Panarin's announcement that this Soyuz had a water recovery capability. A practice exercise was described

where the cosmonauts exited the spacecraft after "splashdown" into the water wearing red flotation jackets. They carried packs with food, water and a miniature radio, and flares to be released both into the air and water to mark their location. The cosmonauts were then helped into lifeboats, which had remained alongside the capsule and the crew during the entire drill.

The second development worth noting was an announcement that this was the first mission to be in continuous communication on all channels—voice and telemetry—with the manned space flight center near Moscow. The mission had tracking support from the *Kosmonavt Yuriy Gagarin* in the western Atlantic and the *Kosmonavt Vladimir Komarov* in Cuban waters, assisted by the Molniya satellite. Western sources were skeptical of the report, however, since during several communication sessions the space crew was heard to use the *Gagarin* or *Komarov* call signs rather than that of the space flight center, and at one point Popovich said he would *relay* greetings from the *Komarov* to Moscow.

The work of the Soyuz 14/Salyut 3 crew included: studies of geological-morphological objects of the Earth's surface, of atmospheric formations and phenomena with the aim of obtaining data for the solution of economic tasks (in other words Earth resources photography); studies of the physical characteristics of outer space; medico-biological research to study the influence of space on the human organism; and tests of the station's improved design. The cosmonauts reportedly had similar eating tastes, with a typical breakfast consisting of bread with ham, cottage cheese with black currants, a honey bun, coffee with milk, and vitamins. Popovich was an avid football fan, so when the world football game was broadcast over the radio, he was given extra work so he wouldn't be tempted to listen in.

An exact copy of Salyut 3 was occupied on the ground to duplicate the actions of the space crew in case any problems developed. For example, when one of the space crew complained of a ventilator that was causing a draft and asked if it could be turned off, the ventilator on the ground-based Salyut was turned off to see if it had any effect on life support systems or other instruments. When no problems developed, the plan was approved.

During their trip in space, the cosmonauts received a congratulatory message from American astronauts visiting Star City in preparation for the July 1975 Apollo-Soyuz joint mission. Several solar flares erupted from July 4–8, but did not affect the crew or the station, although close watch was kept on dosimeter readings to ensure the crew's safety. The normal daily schedule was eight hours of sleep, eight of work, and the remaining eight for exercise, rest, cleaning and making log entries.

After undocking from Salyut 3 at 0903 GMT July 19 and firing their retrorockets as planned, the crew of Soyuz 14 landed at 1221 GMT just 2 km from their planned target 140 km southeast of Dzhezkazgan, Kazakhstan.

Experiments performed on this mission included:

Medical.—With the Polinom–2M equipment, the cosmonauts studied blood circulation to the brain and blood velocity in the arteries before and after physical activity. They also took samples of exhaled air for study on Earth to determine the level of energy expenditures at rest

and while active. For physical conditioning, a universal trainer was provided to mimic walking, running, high and long jumping, and weight-lifting. These exercises were performed every morning and evening. The trainer consisted of a running track or treadmill and a special suit with elastic pulls attached to the belt. The other end of these pulls was attached to the track so that the crew member was pulled onto the apparatus with a force equal to 60% of his body weight. This force was transmitted not only to the waist and legs, but to the shoulders as well, an improvement over the Skylab bicycle according to Russian medical experts, since all muscles were thus exercised.

Other Biological.—A microbiological cultivator was on board and the crew daily sowed bacterial cultures into a growth medium to show the development of bacteria in space.

Earth Resources.—Listed as one of the prime projects on this flight, the cosmonauts spent a great deal of time photographing the Earth's surface and atmosphere. This was described as Earth resources work (of a civilian nature) but the station's characteristics equally or better fitted military reconnaissance work.

The areas mentioned by the Russians as being photographed by the team were: Soviet central Asia, the Pamirs, the eastern coast of the Caspian Sea, the Caucasus, the Ustyurt Plateau, and the Atlantic Ocean where research into global atmospheric processes was being carried out in connection with the international Tropex–74 program (this area was simultaneously photographed by the Meteor satellite). *Aviation Week and Space Technology* reported that objects were placed outside the Tyuratam launch facility during passes by the space station to test the reconnaissance potential of the station.

The crew also made observations of the polarization of solar light reflected by the Earth and its atmosphere during the night, twilight and day horizons for studying the dynamics of the development of optical phenomena. There also was a spectral investigation of the atmosphere with an RSS–2 spectograph to measure the global distribution of gas aerosol components and other atmospheric pollution.

Navigation.—For autonomous navigation, there were measurements of the angular position of celestial bodies relative to atmospheric dust layers and the horizon. An improved Vzor of the type carried on Vostok and Voskhod was used for determining methods of orienting the ship in transitional lighting conditions (going in and out of the Earth's shadow), and orbital orientation when the Sun is low above the horizon and Earth is incompletely illuminated. If one marks the real horizon with a line marked on the instrument and the Sun is in a definite position on the screen, the ship will be oriented correctly.

System Checks.—Another major duty of this mission was the checking of ship's systems. The cosmonauts were assisted in evaluating the exterior of the station by an optical instrument hinged to the outside which could relay images to them and to Earth via a television system. They also checked life support systems, including the parameters of Salyut 3's atmosphere and the water regeneration block, thermo-regulation systems, and radio communication.

Television.—There were several television transmissions, one of the most interesting of which showed effects of vibration on various pendulum instruments. Since some high-precision instruments are affected

by these vibrations, yielding incorrect readings, engineers were quite interested in this demonstration.

c. Soyuz 15.—Launched by an A–2 vehicle on August 26, 1974 at 1958 GMT, Soyuz 15 (Dunay or Danube) was reportedly a continuation of the scientific research and experiments started by Soyuz 14. Its initial orbit was 230 x 180 km.

Altering the orbit to 275 x 254 km with a period of 89.6 minutes and an inclination of 51.6° on the second day of flight, the mission almost immediately ran into trouble when attempts to dock with Salyut 3 were unsuccessful. The pilots, Lt. Col. Gennadiy Sarafanov and Eng. Col. Lev Demin, made repeated approaches to the space station, but each time the ship came within 30–50 meters of its target, the automatic reaction control system aboard Soyuz made excessively long burns, causing it to close too fast.

Since the ferry version of Soyuz does not have solar panels for energy but only chemical batteries, its life in space is limited to about 2.5 days. Thus Soyuz 15 was forced to land at night on August 28. The tracking ship *Morzhovets*, stationed in the Atlantic near St. Helena Island, reported the correct firing of the retrorockets and at 2010 GMT the cosmonauts landed 48 km southwest of Tselinograd in adverse weather conditions. Despite the emergency nature of the landing, rescue teams located the ship quickly and 17 minutes after touch down reached the crew.

The official Russian version, according to General Shatalov, was that the mission of Soyuz 15 was to test the automatic docking system aboard Soyuz for future tanker spacecraft missions to space stations. Thus when the automatic docking system failed there was no attempt to dock manually, although the cosmonauts could have done so. Usually Soyuz closes to within 100 meters of the space station and then manual control is activated. Shatalov stated that even if docking had been accomplished, the cosmonauts would then have undocked and repeated the exercise for practice, rather than enter the space station for an extended visit.

Western observers are skeptical of Shatalov's explanation if for no other reason than that to send a ship into space simply to practice docking techniques when an extended stay is possible is an extremely wasteful exercise. Also, the mission was announced as a continuation of Soyuz 14's work, and indeed both crew members were once again members of the military. So the Russian version that Soyuz 15 was only a docking exercise and that the repeated approaches to Salyut were meant only to gain further information on the malfunction in the reaction control system, are viewed with a great deal of doubt, which the Soyuz 20 flight does little to allay.

12. Soyuz 16

Soyuz 16 (Buran or Snowstorm), announced as a precursor flight for the Apollo-Soyuz Test Project, was launched December 2, 1974 at 0940 GMT and piloted by the prime ASTP backup crew, Col. Anatoly Filipchenko and Nikolay Rukavishnikov. It was a test of the new systems installed for the joint mission and most importantly, the docking procedure. Some biological and photographic experiments were aboard, including some to be repeated on ASTP.

Modifications to the Soyuz included the docking gear, flight and attitude controls, radio communication systems, some new controls added

and consoles modified in the orbital module, addition of an automatic gas analyzer, and changes in the life support system to enable it to handle four people (two cosmonauts and two astronauts). Tests were made of the changes in pressure and air composition that would be used during ASTP. The Russians operate in space under normal atmospheric pressure (760 mm Hg) and a nitrogen-oxygen air content. The United States, however, works in a pure oxygen atmosphere at low pressure (260 mm Hg). In order to minimize the amount of time required for adjusting in the docking module air-lock, the Soviet engineers agreed to reduce their pressure to 520 mm Hg and increase the percentage of oxygen to about 40%. These alterations were practiced during Soyuz 16 and the cosmonauts suffered no ill effects.

NASA was told in advance that this would be an ASTP test, but did not know the exact date and time of launch, since the Russians insisted such information be secret and NASA refused to keep the news from the press. Once the launch was announced, joint tracking exercises were arranged. The tracking stations were: Bermuda and Tananarive (NASA operated); Antigua, Grand Turk, Eastern Test Range, Canton Island, Kaena Point (Hawaii), Kwajalein and Ascension (DOD operated). Mission control in Houston did not operate for this exercise.

The Russians have never announced the initial orbit for Soyuz 16, but NORAD stated it was 137 x 190 nautical miles (352 x 254 km). On the fifth revolution this was altered to 223 x 177 km, with an inclination of 51.8° and a period of 88.4 minutes. As an ASTP test, the craft had to achieve a 225 km circular orbit, and this was accomplished by two more burns: to 240 x 190 km at an unspecified time, and on the 17th and 18th orbits to the final 225 x 225 km, with a period of 88.9 minutes. Although the Russians state that these corrections were part of the planned program in order to test fully Soyuz's systems, some speculate that the initial orbit may have been a trajectory error.

Docking exercises were of primary importance for Soyuz 16. A special practice imitating ring attached to the ship was moved away so Soyuz could maneuver and dock with it (the ring was pulled onto Soyuz with a force equal to that of Apollo). The docking equipment incorporated some of the Soyuz/Salyut gear, for example a spring-mechanical type of shock absorber as opposed to the hydraulic type used by the United States. Some twenty technical operations were planned and carried out to test coupling, link-up and hermetic docking, beginning in the 32nd orbit. The tests were successful.

Filipchenko and Rukavishnikov landed 300 km north of Dzhezkazgan at 0804 GMT on December 8 after six days in orbit. Other experiments carried out during the mission include:

Earth Resources.—Photographs of the Earth were taken for the study of natural resources, and of the horizon to determine the composition and limits of the atmosphere.

Astrophysical.—Photography of the Sun and stars was carried out in preparation for an ASTP experiment which used Apollo to block out the Sun and create an artificial solar eclipse for Soyuz.

Biological.—There were five biological experiments conducted.

(1) The growth of microorganisms in space. Microbes were put in a nutrient medium the first day in space and the cosmonauts watched for their growth. There was a lag for the first few days, but the microbes soon became adjusted to the environment and grew normally.

(2) A determination of what direction sprouts would grow in without the Sun's rays.

(3) The study of fish. In previous experiments, scientists discovered that adult fish lost their sense of spatial orientation in a gravity-free environment. On this mission, Danio rerio fish eggs were brought along. When the fish hatched, they exhibited no orientation problems as the adult fish had.

(4) Samples of microbes were taken from different parts of the Soyuz craft and from the cosmonauts themselves (hair and skin) to test microbial transfer. This was repeated on the ASTP mission to determine if any contamination occurs when one space crew is visited by another, as might happen in long-duration space stations.

(5) Zone-forming fungi were studied for two reasons. First, these fungi develop a new growth ring every 24 hours on Earth and scientists wanted to see how often one would grow in space where a "day" is only 90 minutes long. In addition, the fungi were placed inside a device called "Ritm" which had a dosimeter mounted on the outside to measure the amount of radiation entering the flask to see if it had any effect on the fungi. During ASTP, fungi were flown on both ships to see how different amounts of radiation in various areas of space would affect the organisms, since Apollo and Soyuz would travel in different parts of the sky except for the time they were docked together.

13. Soyuz 17 and 18 with Salyut 4

Still in orbit at the time of this writing, Salyut 4 has already hosted two manned missions which totaled 93 days: Soyuz 17 for 30 days, and Soyuz 18 for 63. In turn these missions broke the Soviet space endurance record and brought them closer the American record of 84 days on Skylab 4. Salyut 4 also has accommodated one unmanned mission, Soyuz 20.

a. Salyut 4.—Salyut 4 was launched on December 26, 1974 into a 270 x 219 km orbit, inclined at 51.6°. This was soon raised to a 350 km circular orbit, higher than previous Salyuts, and done apparently to conserve fuel. There were again modifications to the space station, for example easier access was provided to certain mechanical areas of the ship for repair and replacement of parts.

The length of the space station was announced as 23 meters (see page 188) with the same volume (100 cubic meters) and weight (over 25 metric tons).

The solar panels were described as individually rotatable and having a total area of 60 square meters producing 4 kilowatts of power. The panels turn automatically on signals from solar gauges indicating what position the Sun is occupying at any given moment. There also was a third bank of solar batteries added.

The space station has an MMMS, micrometeorite monitoring system, with 4 square meters of panels serving as sensors. At first particles were measured acoustically, but now a capacitator type is used which registers both the impact and penetrating power of each particle. Two thin metal plates, which are insulated by a layer of teflon, close together when struck by a particle and a pulse is sent to the control center. The skin of the station (which reflects ¾ of the light rays hitting it) serves as a shield from these particles. If a meteorite hits

the ship with a velocity greater than 4 km per second, the particle explodes on contact and a second layer of skin picks up the debris.

The Russians also described their thermal control system. The walls of Salyut are made of "screen-vacuum" heat insulation which precludes heat exchange between the station and space, and are made of many layers of synthetic film sprayed with aluminum (they claim a piece of dry ice placed between layers of this material would not melt for hours even in direct sunlight). To heat the station, an intricate system of radiators is used which both collects solar heat and throws off surplus thermal energy. Three or more backup systems are available.

Salyut's interior was again described, broken down into three separate areas: assembly, transfer and work. The assembly area is unpressurized and contains the fuel tanks and orbital and orientation engines. The transfer area is the cylindrical part of the ship, two meters in diameter and three meters long, where two of the seven work posts are located at windows for navigation and scientific observations. The "Raketa" vacuum cleaner is kept here also. In this area there is a long sleeve of rubberized fabric which extends into the ferry craft to feed it fresh air. The walls in this part of the ship, as well as in the work area, are painted in soft greens, yellows and blues.

The work compartment is the main part of the space station and consists of two cylinders connected by a conical bridge. The smaller cylinder is 2.9 meters in diameter and 3.8 meters long with the solar panels attached to the outside. The large cylinder is 4.15 meters in diameter and 4.1 meters long and has a cone which broadens downward where scientific instruments and equipment are kept at a work station. To the left and right of the cone are refrigerators for storage. The conical bridge is 1.2 meters long.

The Russians gave the following description of Salyut 4 from front (near the transfer tunnel) to back.

The main control panel, housing navigational instruments, clocks, radio communication monitors and controls, the Globus navigational indicator to show what part of the Earth is being passed over, and two keyboard command signaling devices, faces the transfer tunnel and has two work stations. To the left of the main panel are life support controls with regeneration cylinders for purifying the air on both sides of the panels. At the right of this is another work station for control of scientific instruments. Another work station for medical research is located in the conical bridge section.

Behind the main command post, in the center, is a table for eating. To the left, looking from the transfer tunnel, and behind the panels, is a small cupboard for plates, knives, forks, etc. There are two heaters with tubes for soup and coffee. These are heated to 70° C and then the device turns itself off automatically. Hot and cold water are fed directly to the table.

Beyond the table on the side panels are grids covering the cooling-drying assembly which sucks in air, cools it, and feeds it back. Fans are provided for circulation of the air.

Farther back is the medical area where a swivel chair is located for experiments on vestibular reaction, as well as a closet for medical instruments. At the right is exercise equipment, and above them on the right is a tape recorder for music. At the end of this cylinder is the

sanitary-hygiene area which is separate from the rest of the rooms and has forced ventilation.

The Soviet press release did not mention the largest piece of equipment on board Salyut 4, the space telescope. From other sources its location in the center of the large cylinder is known.

Although both Soyuz 17 and 18 docked with Salyut in the usual manner, with manual control being engaged at 100 meters, the Russians announced that manual control could be activated as early as 200–300 meters from the station (although this might not always be wise since deviations in the course could occur) or the entire operation could be carried out automatically. They suggested the latter method was not always feasible due to an area of "silence" where a crew can respond more quickly than an automatic sensing device.

b. Soyuz 17.—The launch of Soyuz 17 came at 2153 GMT on January 10, 1975. Its crew, Lt. Col. Aleksey Gubarev and Flight Engineer Georgiy Grechko, were boosted into an initial low orbit which by the fifth revolution was raised to 354 x 293 km, inclined at 51.6° with a 90.7 minute period. At this point, Salyut was in a 350 km circular orbit, so two maneuvers were required to put Soyuz into a docking position. The actual docking occurred at 0125 GMT January 12 in the usual manner.

The significantly higher orbit of this mission suggested that its tasks were astrophysical in nature, and indeed the Russians announced the following projects for the space crew: research into the physical processes and phenomena in outer space, Earth resources photography, medico-biological research, and testing of the station's systems and design.

Communications were supported by the Molniya satellite and three tracking ships in the Atlantic: the *Akademik Sergey Korolev* near Sable Island off Canada's east coast, and the *Ristna* and *Nevel* in the southern Atlantic.

During the 30 day mission, the cosmonauts followed a cycle of six days of work and one of rest. They typically ate four small meals daily, with one-half hour of exercise before breakfast, one hour between breakfast and lunch, and one hour between lunch and dinner. No shower was provided, so the cosmonauts washed themselves with moist gauze napkins moistened with lotion. Shaving was accomplished with either a safety razor or an electric one which sucked the whiskers into a container. During the flight, Gubarev lost 2.5 kg of body weight while Grechko lost 4.5 kg. Physicians explained the flight engineer's greater loss as a result of extra work performed at the expense of sleep.

At 0608 GMT on February 9, Soyuz 17 undocked from Salyut and at 1103 GMT landed 100 km northeast of Tselinograd. The landing apparently took place in a blinding snow storm, with wind velocities up to 20 meters per second, a visibility of 500 meters, and a ceiling of 250 meters. Despite the adverse weather, rescue teams were on the scene immediately, and within ten minutes the cosmonauts were on board a helicopter.

The announced aggregate weight of the scientific apparatus on this mission was 2.5 tons, and was used for the following experiments:

Medical.—A veloergometer (apparently part of the Polinom apparatus) was used to measure and predict the functioning of the cardiovascular system, tone of the blood vessels, venous circulation, and

circulation of blood to the brain. They also checked the effects of decompression on the lower part of the body with a special (Chibbis) decompression suit that was worn not only during exercises, but also for hours at a time while the cosmonauts performed routine daily tasks. Samples of blood and exhaled air were taken for analysis on Earth, as well as microbes from various parts of the ship. The Russians also checked vestibular reaction by use of a swivel chair, and used a "Plotnust" device for ultrasonic measuring of changes in the composition of bone tissue. There also was an electric muscle stimulator, Tonus, which could send pulses to any specific set of muscles to exercise them.

Exercise equipment included the treadmill used on other flights (which was reportedly 90 cm long and 40 cm wide), and a new addition, a bicycle. This was described as a comfortable chair with pedals, turned alternately by the feet and hands, connected to a generator which stored the electricity that was produced. They followed a regime of three days of regulated exercises, and then one day where they could choose whatever they liked.

Other Biological.—Experiments continued with microorganisms and higher plants, as well as with certain biological species. An experiment called "Oazis" involved growing leguminous plants, specifically peas, which sprouted in three weeks. The relationship between this "Oazis" and the Oazis–1 and –2 on earlier flights is unclear. Fruit flies (Drosophila) and the embryos of frogs that developed in space were observed to check their biological development in a weightless environment.

Earth Resources.—Not a major experiment in Soyuz 17, the crew only performed a small amount of Earth photography covering the following areas: the Kurile Islands, the Caspian depression, Central Asia, the southern European portion of the Soviet Union, the Far East and Kazakhstan.

Atmospheric.—The "Emissiya" system was used to study the red line of atomic oxygen in the atmosphere at a height of 250–270 km. Spectrographs in the rear part of the space station scanned the Earth's horizon in areas where the electron system was active. These studies will be valuable both for meteorology and for determining flight dynamics for satellites. Related to those studies, the crew continued research into the characteristics of plasma flow just outside their space station to see how it affected the rate of orbital decay.

Earth Radiation.—The Earth's radiation was studied with an infrared telescope/spectrometer (ITS–K). The telescope has a 300 mm diameter mirror, and the slit of the spectrometer is precisely in the telescope's focus. Here the radiation entering the device hits a fluorite prism. The apparatus receives wavelengths from 1–2 to 7 microns and has a 10 x 20 minute field of view, and the spectrometer has a resolving power of 600 lines per millimeter.

Although the Earth's surface, the Moon and the galactic planes were all studied by the infrared device, its main target was the Earth's atmosphere. Spectra of solar radiation which had passed through the atmosphere were recorded at sunrise and sunset. To do this, the slits of the spectrometer were placed parallel to the Earth's horizon. The information is needed for determining the temperature of the atmosphere as well as distribution of water vapor and rare gases such as ozone. The atmosphere can only be explored to about 35 km with air-

craft, and although sounding rockets can travel higher, they leave vapor trails which do not permit close examination of some aspects of the atmosphere's characteristics.

In order for the readings to be accurate, the apparatus must be kept extremely cold. Until this mission, a conventional cold generator with compressors was used. But a great deal of energy was required for this method, so this time the Russians provided an ice coat of solid nitrogen which maintained the proper temperature quite successfully.

Astrophysical.—Two X-ray telescopes were used to study radiation from various areas of the universe. A "Filin" set of spectrometers was mounted on the outside of the station to detect the radiation by sensors, and was linked in parallel with a set of two optical telescopes (70 cm long with a 6 cm diameter and 1 degree field of view) to identify exactly what object was emitting the radiation. They used two modes of observation: one with the axis of the telescope permanently fixed on one area of the sky, and the other where the ship's commander oriented the ship and the flight engineer positioned the telescopes, as had been done with Orion–2. The Russians announced that for the first time an autonomous system of stellar orientation was used to train the telescope, but provided no further details. The second X-ray telescope RT–4, was not described until the Soyuz 18 mission.

During their extensive operation of this system, the crew studied the Crab Nebula, supernova explosion remnants in both the Vela and Puppis constellation, the Ori (sic) star (probably Rigel), white dwarfs, neutron stars and black holes, as well as the background radiation of the galaxy along its meridian.

Solar Photography.—A telescope made in Crimea was used for studies of the dynamics of the Sun in the ultraviolet. The orbital solar telescope (OST) was equipped with a KDS (for Krymskiy Difraktsionnyy Spektrometer—Crimean Diffraction Spectrometer) and it studied specific areas of the Sun, not the entire disc at one time. Although the Russians announced that the telescope had operated for two weeks before the crew came aboard, they also reported that the pointing system had malfunctioned causing the Sun to blind the main mirror. (The apparatus had two mirrors, the main one 25 cm in diameter with a 2.5 meter focal length, and a rotating mirror.) To correct this and make the telescope operational for the remainder of the flight, experts at the Crimean Astrophysical Observatory decided to reposition the rotating mirror so that the Sun's rays would be reflected into the main mirror. To accomplish this, the cosmonauts had to position the ship so that the telescope's axis was pointing directly at the center of the Sun. This was no easy task, for the crew had to measure the time it took for the rotating mirror to move from one support to another in its normal mode of operation, so they could calculate where it had to be stopped to assist the main mirror. The only way to do this was by listening to the mirror's movements, which the crew did with a stethoscope from their medical kit. Not only did this make the device operational, but once again proved man's usefulness in space.

Although the main mirror was in a conical niche to protect it from micrometeorites, the cosmonauts had to resurface it by spraying a new reflective layer onto it. The Russians were delighted that the process worked well, for it was a deciding factor in their astrophysical plans for future space stations. If the surface could not be recoated, there

would be no use in sending up other telescopes for long duration exploration.

The Sun was quiet during the Soyuz 17 mission, but good photographs were taken of dim flocculi (light patches on the Sun barely discernible from Earth) which exhibited bright features. These areas were simultaneously photographed on Earth for comparison purposes.

Navigation.—Two navigation systems for autonomous control of the station were mentioned, and their relationship to each other is vague. Reports stated that daily tests were made of the Kaskad (Cascade) autonomous navigation system, consisting of an onboard computer that makes navigation measurements and determines orbital parameters. The Russians hope it will reduce fuel consumption for orienting the ship. The "Delta" system was described in much the same way, although it seems as though this system was a functioning part of Salyut, not an experimental version like Kaskad.

Communications.—A new method of communication was experimented with that utilized a teletype system called "Stroka." This time the crew only tested the system, so it was used primarily for personal communications from family and friends, press reports on the mission, and basic information on orbital parameters. The system apparently works the same way newspaper teletypes do, with the message coming out on a strip of paper. This has the advantages that a permanent record is provided of communications from Earth, and it relieves the crew of the need to be present when the message arrives. They can read it whenever they have time.

c. April 5th Anomaly.—On April 5, 1975 at about 1103 GMT, the Russians launched a spacecraft with the announced purpose of docking with Salyut 4 and continuing scientific experiments. But a stage separation malfunction of the A–2 booster forced the mission to be aborted and the crew, Col. Vasiliy Lazarev and Oleg Makarov, found themselves landing in cold, snowy Siberia southwest of the town of Gorno-Altaisk, 1,600 kilomters away from the launch site and only 320 kilometers north of the Chinese border. After the failure, the mission was renamed the "April 5th Anomaly" and the Soyuz 18 designation it would have received was given to the next craft in the series.

TASS did not announce the shot until two days later, presumably to give the crew time to be rescued and their health assessed. It is suspected that they spent the night at the landing site before recovery teams could meet them. They reportedly exited the spacecraft shortly after landing and built a fire.

The primary significance of this failure was its relationship to ASTP, to be launched only three months later. Konstantin Bushuyev, Soviet program director for ASTP, assured his American counterpart, Glynn Lunney, that the launch vehicle used in this instance was an old version of the one to be used in July, and that none of the systems in common were suspect in the malfunction. This raised a lot of eyebrows in the West for several reasons. First, there had been no suspicion that the A–2 vehicle had two versions, although experts were aware of differences in the Soyuz craft itself. Second, since the Soyuz's docking target, Salyut 4, was in a substantially higher orbit than that to be used for ASTP, it seemed unlikely that a less capable launch vehicle would be used. Third, the A–2 is used for unmanned as well as manned missions. Why the Russians would use the older version on a manned flight rather than using them up on unmanned missions is unclear.

NASA did not appear overly concerned with the failure, however. The Russians were preparing two complete sets of hardware for ASTP, so if one failed another would be ready on the pad. Also, a failure before reaching orbit would not affect the safety of the American crew.

Senator Proxmire, chairman of the Senate subcommittee dealing with NASA's appropriations, did not concur however, and called for a CIA briefing on the capabilities and safety of the Russian space program. Comments on this classified briefing are given in the annex to this chapter.

d. Soyuz 18.—Six weeks after the failure of the Soyuz flight, Soyuz 18 was launched to dock with Salyut 4. At 1458 GMT on May 24, 1975, Col. Petr Klimuk and Flight Engineer Vitaliy Sevastyanov were boosted into orbit by an A–2 vehicle. By the second revolution their orbital parameters were 247 x 193 km, inclined at 51.6°, with a period of 88.6 minutes. After at least two maneuvers, a normal docking was achieved with Salyut 4 on May 25. The orbit after docking was 356 x 344 km, with a period of 91.3 minutes.

Although the Russians reported that the crew required a "normal" amount of time for adaptation to weightlessness, they noted that this period was ten days, somewhat longer than previous crews needed. In a new medical experiment, experts decided to adopt ten days as an adaptation period in reverse, that is, use the ten days before the end of the mission to begin preparing the cosmonauts for Earth conditions. Remarking that the Soyuz 17 crew found physical exercise inadequate, physicians placed Klimuk and Sevastyanov on a high salt diet and encouraged them to drink a lot of water to increase body fluids. Although both reported feelings of dizziness such as those they had experienced during initial adaptation, after landing on Earth doctors reported the experiment was successful.[13]

The mission carried 90 scientific and experimental installations to work in the following areas: studies of the Sun, planets and stars in various bands of the spectrum; investigation of geological-morphological objects on the Earth's surface; physical processes in the atmosphere and in cosmic space; medical-biological tests; and tests of the station's systems and design.

During the 63 day mission, the joint Apollo/Soyuz launches took place and two communication sessions ensued between the crews of Soyuz 18 and Soyuz 19. The issue of having two Russian manned missions in space at the same time was another topic for Senator Proxmire's CIA briefing.

The crew landed on July 26 at 1418 GMT, 56 km southwest of Arkalyk, Kazakhstan. Although they set a new space duration record for the Soviet Union, they did not surpass the American record of Skylab 4.

Since most of the experiments for Soyuz 18 were continuations of Soyuz 17 projects, there is no need to discuss them in detail here. The Polinom and Chibbis suit medical experiments were continued, onions and peas were grown in the Oazis system, and Drosophila development was studied. Research into the atmosphere was continued with "Emis-

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[13] TASS, Moscow, July 29, 1975, 0600 GMT. In a subsequent report (TASS, September 18, 1975) the Russians make no reference to this report, and say that the cosmonauts needed only 4 days for adaptation.

siya," as was solar photography and other astrophysical observations, and the Stroka communication was utilized again.

Other experiments included:

Earth Resources.—A great deal of attention was given to Earth photography this time, supposedly so they can compare photographs of areas in winter with those taken in summer. Covered in this mission were: the European part of the Soviet Union, the Transcaucasus, northern Kazakhstan, republics of Soviet Central Asia, Primorye territory, Kurile Islands, Rostov and Volgograd oblasti, the Ukraine, Turkmenia, the Pamirs, Sakhalin Island, the eastern part of the Baykal-Amur railway, the Orenberg region, the Volga, maritime areas, mountains, sea currents, and shelves and deposits on beds of rivers at their mouths. All in all, over 8.5 million square kilometers were photographed.

Atmospheric.—Experiments that had been conducted on previous flights into the nature of the space immediately surrounding Salyut were continued and given the name "Spektr." They involved investigations of the physical properties of the cosmic environment, specifically interaction between space vehicles and space. An analyzer on board the station oriented in the direction of flight measures the density, composition and temperature of particles striking the hull of the ship to see how they affect orbital decay.

Astrophysical.—The two X-ray telescopes were used again, and a description of the RT–4 mirror X-ray device was given. This telescope was used to study soft X-radiation carrying photons with energy less than one kiloelectronvolt. It had a parabolic mirror with a diameter equal to 200 mm, a photon counter, a system of gas filling, and an electron device for primary processing of information. It looked at known sources of radiation rather than scanning for unknown sources as the Filin spectrometer had done, and had an independent orientation system accurate up to 15 seconds of arc. The crew studied the constellations of Scorpio, Virgo, Cygnus and Lyra, focussing especially on X–1 Scorpio and X–1 Cygni. The latter is suspected of being the ever-elusive black hole, although its correct classification now is a neutron star. Because of the atmosphere, exact readings on this object are not possible from Earth, and the Russians stated they could now measure its mass, size, luminosity, density and temperature.

Navigation and Tracking.—A new tracking technique was tried out using lasers. The laser pulses were sent from Earth and reflected back by an optical corner reflector installed in the ship. These trials were successful.

Concerning navigation, no real clues were given as to the distinction between "Delta" and "Kaskad." It is possible that Delta is the system presently being used, which has a radio altimeter and other instruments to compute orbital parameters, and Kaskad is an innovation for the future using only stars and other celestial objects for guidance.

Systems.—The crew practiced thermal regulation and life support in various modes. They also used a freon installation to study how liquids are affected in orbital flight. The results will be used for creating hydraulic systems for spacecraft.

14. Soyuz 19, the Apollo-Soyuz Test Project.

Due to the significance of this first joint space mission, the subject is treated separately in the annex to this chapter.

15. Kosmos 772.

On September 29, 1975 the Russians launched Kosmos 772 into a 320 x 201 km orbit, inclined at 51.8°. Soyuz-type telemetry on 20.008 MHz was monitored in Kettering and Akrotiri, Cyprus. Like the Soyuz ferry ships, Kosmos 772 had no solar panels, but it remained in orbit for three days, like Kosmos 670 and a day longer than most other missions of its kind, suggesting either greater battery capacity or lessened electrical loads such as that which would be associated with a one-man crew. Some speculated that it might be a system test for return to three-man crews.

16. Soyuz 20 with Salyut 4.

In mid-November the Russians launched an unmanned Soyuz 20 to dock with Salyut 4. After several days, they announced that on board the ship were biological specimens for parallel experiments with the Kosmos 782 mission. Since that places Soyuz 20 under the biosat category, the discussion of this flight is deferred to that section (see page 223).

III. The Zond Program of Precursors to Manned Circumlunar Flight

The now inactive Zond program of precursors to manned circumlunar flight began in 1968 (although earlier failures not officially linked to this program are suspected.) After five flights, the program was terminated for reasons still unknown. Speculation as to what happened to this program as well as Soviet plans for manned lunar flight will be discussed later.

The view had long been held that just as the U.S.S.R. was first in Earth orbit, so would they be first to send men around the Moon. The 1965 missions in which Proton payloads were flown using the D class vehicle suggested that a launch vehicle was available to support such a mission. The same common wisdom suggested a Soviet Moon landing by 1972, and this was the estimate President Kennedy hoped to beat with Apollo. A vigorous and successful development of the D-1-e booster might have realized the first of these predictions and provided a stunning celebration of the fiftieth anniversary of the Soviet state in November 1967.

On two occasions in 1967, according to British measurements, the D-1-e was used for flights which attained Earth orbit only. These were on March 10 with Kosmos 146 and on April 8 with Kosmos 154. The flights occurred just one lunar month apart, so possibly were Zond precursors that failed, and if so, may have set back the Soviet timetable. There may have been other, later attempts which were even less successful, as they did not reach Earth orbit. Newsweek magazine claimed that on November 22, 1967 and April 22, 1968, Zond flights to the Moon were attempted and failed. There are no official statements to prove or disprove that contention.

A. ZOND 4

On March 2, 1968 Zond 4 was launched [14] and it is now judged as a

[14] As detailed in Chapter Two, Zond 1–3 were planetary probes; Zond 1 to Venus in 1964; Zond 2 to Mars in 1964; and Zond 3 past the Moon (where it took high quality pictures of the far side) and on to Mars.

diagnostic engineering test of subsequent Zond flights (which the Russians themselves identified as fully capable of carrying a human crew around the Moon). It wasn't until 1971 that a drawing was released showing the ship to be virtually identical in external appearance to Soyuz, but without the forward work module. The British Royal Aircraft Establishment has estimated its weight at 4,820 kg, with a length of 5.3 meters and diameter of 2.3 meters. This estimate may very well understate the weight which could have been as much as 5,800 kg.

Zond 4 was launched one half lunar month away from the ideal time to launch toward the Moon, and was sent in a direction opposite to the Moon. Using the D-1-e, it was placed in a parking orbit around Earth, and then was fired from its orbital launch platform out to what the Russians called "outlying regions of near Earth space." Presumably it was intended to go out about as far as the Moon's orbit, but would afford a better opportunity for controlled return to Earth without lunar gravity being as operative as during a flight around the Moon itself. Considering the significance of a new program of such magnitude and portent, the failure of the Russians to give any further report on the flight strongly suggests that it was not a success, but there is no evidence in the public domain either way.

B. ZOND 5

On September 14, 1968, Zond 5 was launched in a similar fashion, but this time on a course to circle the Moon. On September 17 a mid-course correction was performed to bring it to the correct path to swing around the Moon at a distance of 1,950 km. Another correction was later made on approach to the Moon relating to its return to Earth.

The ship was described as consisting of two compartments. One was the recoverable cabin, with its heavy layers of ablation material, parachute packs, scientific instruments, radio communications equipment, heat regulating system and power supply. The other was the service module with two large solar cell panels extending like gull wings, a radio telemetry system, control equipment, orientation and stabilization systems, heat regulation system, chemical batteries, and rocket propulsion systems for course corrections. Optical sensors and radio antennas were also carried externally.

Although the mission was primarily an engineering test, it also carried cameras and a biological payload. The cameras returned for the first time high quality photographs rather than radio facsimile pictures. The biological payload consisted of: turtles; wine flies; meal worms; a spiderwort plant with buds; seeds of wheat, pine and barley; chlorella in various nutrients; lysogenetic bacteria of various types; and other unspecified living matter. Upon recovery, the turtles were active, but had lost about 10 percent of their body weight and had excessive glycogen and iron in their liver tissue as compared with Earth-based controls. In 1971 the Soviets revealed that the barley and pine seeds showed some changes, as expected because of their known sensitivity to radioactivity, but no changes in the other plants were noted.

Seven days after launch, Zond 5 returned to Earth. This was the first return of a spacecraft from a deep space mission (although similar high speed reentries had been simulated by U.S. craft) and it had to

hit a reentry corridor between 35 and 48 km above the Earth. If the ship had approached Earth 10 km lower, it would have been destroyed by overloads of heat and pressure; 24 km higher and it would have skipped out of the atmosphere.

Entering the atmosphere at 10,900 meters per second, it was slowed aerodynamically to 200 meters per second and then deployed a parachute at 7 km altitude. The approach to Earth was over the South Pole, and Zond 5 then made a ballistic reentry, landing in the South Indian Ocean as it headed north at coordinates 32°38′S. by 75°33′E. The capsule had been exposed to heat levels of 13,000°C during reentry.

This was the Russians' first water recovery of a space capsule, and the Soviet account said it was especially difficult because the splashdown occurred at night and the payload had to be "discovered." Recovery was directed by the Academy of Sciences rescue service and the tracking ship *Borovichiy* which used radio direction finders and searchlights. An oceanography ship, *Vasiliy Golovnin*, carried the capsule to Bombay where it was transferred to a Soviet AN–12 cargo plane and flown to the U.S.S.R.

C. ZOND 6

Zond 6 was launched with a D-1-e on November 10, 1968. A total of three orbital corrections were made: the first on November 12, and the other two after passage around the Moon on November 14 at a distance of 2,250 km.

Much of this mission was a repeat of Zond 5. Equipment was carried to study the effects of radiation on living creatures (although no description of the biological payload was given) as well as a photoemulsion chamber to record the paths of cosmic rays and a device to measure the impacts of micrometeorites.

More lunar photographs were taken with a standard aerial camera which had a focal length of 400 mm, frame size of 13 x 18 cm, and a resolution of 50 lines per millimeter. While Zond 3 facsimile pictures could provide 1.2 million data bits per picture, each Zond 6 photograph had 134 million data bits. Some of the views made stereo pictures of the Moon possible, both on the near and far sides. The film itself measured 29 cm wide and 28 meters long.

On November 17, Zond 6 returned to Earth in the same manner as Zond 5 with one important difference. It approached at 11 km per second, used aerodynamic braking to slow to 7.6 km per second, and then the control mechanism on board was used to orient the craft so that it developed considerable lift and skipped outside the atmosphere again. Then it made a second reentry into the atmosphere and by continued operation of its orientation system made a controlled landing in the Soviet Union in the "preset district." This was a very impressive achievement, to travel so many thousands of additional kilometers beyond the point of ballistic reentry.

The Russians explained that the South Pole approach was the only practical one for returning Zond payloads to the Soviet Union, because a direct ballistic approach would bring too heavy an overload for a human crew. The southern approach permits the long double entry, skip return. Academician G. I. Petrov noted, however, that the prolonged reentry increased the effect of heat flow, and added a con-

siderable strain to the structure of the heat protecting system.[15] He also stated that the G load for Zond 5 reached 10 to 16 G's and implied that for Zond 6 it was more like that for Soyuz (3 to 4 G's). This was later reported to be 4 to 7 G's for the first immersion.[16]

The Russians finally made a formal announcement that Zonds 4, 5 and 6 were all aimed at perfecting a manned space ship to go around the Moon. Although all the indications were that Zond 6 performed well, Academician Blagonravov stated that further unmanned tests would be required before men could be sent.[17]

D. ZOND 7

The launch of Zond 7 came on August 7, 1969, with the announced purpose of further engineering tests and more photographs of the Moon's surface. On August 9 a course correction was made so that it circled the Moon on August 11 at a distance of 2,000 km. The craft returned to Earth August 14, in the same manner as Zond 6 and from all outward signs it was quite successful. Only two orbital corrections had been required. Recovery was announced more promptly than for earlier flights.

The only difference between this mission and the others was that it took color as well as black and white photographs. Sessions of picture taking were held on August 8 for Earth, and on August 11 for the Moon (twice) and the Earth as it set beneath the Moon's horizon. The hope was that color pictures from different angles would reveal differences in the microstructure of lunar material, and that new features of the Earth would be discovered.

E. ZOND 8

The only Zond flight of 1970 and the last in the series was Zond 8 on October 20. When it was 328,000 km from Earth, the craft was observed by telescope at the Sternberg Astronomical Institute in the Transili Alatau of Central Asia. Photomultiplier tubes made it possible to find its movement against the star background to determine its trajectory very precisely. Similar pictures were taken at other times both by the Institute and the Crimean Astrophysical Observatory.

On October 21, Zond 8 transmitted the first television images of Earth, from a distance of 65,000 km, and these continued for the next two days. On the 24th, after a mid-course correction, the craft passed within 1,100 km of the Moon, and both color and black and white pictures were taken of the surface.

This mission used a quite different approach to Earth upon reentry: over the North Pole instead of the South. This had the advantage that during most of the reentry, Soviet ground stations could control the flight. This also proved to be the second Russian water recovery, with the craft splashing down 725 km southeast of the Chagos Archipelago in the Indian Ocean, probably in a ballistic reentry. This time recovery ships were sufficiently well positioned to see the actual reentry, and although it was again at night, the capsule was quickly picked up by

[15] Izvestiya, Moscow, November 19, 1968, p. 2.
[16] Moscow Rural Life, Nov. 24, 1968, p. 4.
[17] Moscow Radio, Dec. 10, 1968, 1200 GMT.

the *Taman*. It was then transferred to the *Semyon Chelyuskin* for the trip to Bombay, where it was put aboard a cargo plane for the flight back to the Soviet Union.

IV. The Soviet Manned Lunar Landing Program

This section provides a brief discussion of whether the U.S.S.R. had a program for landing men on the Moon. A more detailed examination of this subject as well as an exploration of the entire range of possible future space missions can be found in Chapter Seven.

The threat of the Soviet Union reaching the Moon before the United States gave the American space program the impetus (emotional and financial) it needed to achieve what it has today. Thus the question of whether there was indeed a "race" to the Moon or not is of no mean import to those who paid $25 billion to "land some clown on the Moon" as detractors are fond of saying.

Unfortunately there is no definitive way to prove the case either way. All that is attempted here is an analysis of statements made by those who should have known the direction of their space program prior to Americans landing on the Moon in 1969, and their technical capabilities.

A. VERBAL EVIDENCE

Prior to 1969 there was a wealth of statements reflecting the position that the Russians were interested in landing on the Moon and an extensive collection of these quotes (as well as statements on other aspects of the space program) are given in the 1966–70 edition of this report (pp. 359–384). If the case were to be proved on verbal evidence alone, there would be no question but that a manned lunar landing was high on the Soviet agenda. A sample of statements prior to July 20, 1969:

Cosmonaut Feoktistov outlined the Soviet space program as involved in four progressive steps: (1) Study of geophysics and solar phenomena, and unmanned flight to the Moon and planets; (2) study of space biology and man's adaptability; (3) learning to link up and assemble in orbit a launch facility, as a step toward landing an expedition of men on the Moon; and (4) sending landing expeditions of men to Mars and Venus with fundamentally new rocket and spacecraft systems. (TASS, December 31, 1964, 1524 GMT.)

Professor Yelizavetskiy stated: "The launching of the Voskhod 2 and Leonov's space walk strengthens the confidence that the first people on the Moon will be Soviet people." (Moscow Radio, March 19, 1965, 0730 GMT.)

Cosmonaut Leonov said there is a regular, scheduled preparation in the Soviet Union for the conquest of space and the time is approaching when men will land on the Moon. The task of landing has been solved. (Budapest MTI, April 6, 1966, 0907 GMT.)

Academician Keldysh said it is now clear that soon man will land on the Moon and on other planets. (Moscow Radio, October 24, 1967, 1400 GMT.)

Academician Konstantinov stated that landing a man on the Moon does not belong to the realm of fantasy any longer. This is an affair of the nearest, of the most imminent future. Everything is already prepared for this undertaking. There are a few details like radiation hazards, but these will be solved soon. Perhaps the Americans even will be first, but it is still a competition and a question of prestige. (Vjesnik, Zagreb, January 21, 1968, p. 8.)

Cosmonaut Shatalov told the Hungarian news agency correspondent in Moscow that the Soviet Union will require "six, seven, and perhaps more months"

of preparations to land on the Moon. "Who makes the better preparations will get to the Moon first, and it is our wish to do so." (Belgrade TANYUG, April 9, 1969, 1116 GMT.)

Cosmonaut Leonov: "The Soviet Union also is making preparations for a manned flight to the Moon, like the Apollo program of the United States. The Soviet Union will be able to send men to the Moon this year or in 1970. We are confident that pieces of rocks picked from the surface of the Moon by Soviet cosmonauts will be put on display in the Soviet pavillion during the Japan World Exposition in Osaka in 1970. (Yomiuri, Tokyo, June 14, 1969, p. 10.)

The above comments give a strong basis for the official American contention that there was a race to the Moon underway. Those who disagree use two 1963 statements as the core of their argument.

The first was made by Sir Bernard Lovell, Director of the Jodrell Bank Radio Observatory in England. Upon returning to London from a tour of several astronomical centers in the Soviet Union, Lovell reportedly said "the Russians are not interested in sending men to the Moon." Later, however, during a trip to Washington, Lovell maintained that the press had misquoted him and that he had "every reason to believe that the Russians are trying to reach the Moon every bit as fast as the Americans." [18]

The second comment was by then Soviet premier Nikita Khrushchev in response to a reporter's question: "At the present time we do not plan flights of cosmonauts to the Moon. . . . We do not wish to compete in sending people to the Moon without thorough preparation." [19] The first part of the statement was taken by U.S. critics as demonstrating that we were racing with no opposition. But the second phrase does not imply that the Soviets had no interest in the Moon, only that safety considerations should come first.

One must also take into account that Khrushchev was an expert politician and he knew that if the American public could be convinced that there was no race, there was a good chance the U.S. space program would slow down, giving his country more time to develop their own hardware.

B. TECHNICAL CAPABILITY

In order for the Soviets to land men on the Moon they would have to demonstrate a technical capability in several areas. Three of the most crucial are discussed here: rendezvous and docking in orbit; a spacecraft with adequate controls for navigation and guidance, life support, and heat regulation; and a launch vehicle capable of sending sizable payloads to the Moon.

1. Rendezvous and Docking

As the earlier sections of this chapter indicate, exercises related to the rendezvous and docking of two ships in Earth orbit have played a major role in the Soviet space program since its beginning. Their first manned "near pass" came with the Soviet Union's third and fourth spaceflights, Vostok 3 and 4. The mission was repeated with the next two flights, Vostok 5 and 6.

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[18] Young, Hugo, Bryan Silcock and Peter Dunn. Journey to tranquillity. Garden City, New York, Doubleday, 1969 : back cover.

[19] Oberg, James E. Russia meant to win the "moon race." Spaceflight, London. v. 17, May 1975 : 163–4.

Docking was the next step, and may have been the mission for the ill-fated Soyuz 1 and a second ship never launched. After the death of Soyuz 1's pilot, the manned program slowed down and docking exercises were practiced by unmanned ships. Thus in 1967 the Russians achieved their first docking, between Kosmos 186 and 188. After a second unmanned practice with Kosmos 212 and 213, an unsuccessful attempt was made with the manned Soyuz 3 and unmanned Soyuz 2. Not until the Soyuz 4 and 5 link-up could the Russians finally celebrate a success with manned ships. This was not until January 1969, however, and the Americans had already sent three men into lunar orbit and brought them home again. The "race" had been won, for most purposes.

2. The Spaceship

Although a case could probably be made that all the manned flights and their precursors were devoted in some respect to developing systems capable of long duration spaceflights, the focus here is on the Zond series, for the Russians themselves announced they were tests related to manned circumlunar voyages.

The Zond capsule is a modified Soyuz, with the orbital workshop removed and a still unidentified object put in its place (there is speculation that this is a docking collar). A large parabolic radio antenna was added for long range communications, and the Zond may have a reinforced heat shield. These Zond missions were described in an earlier section of this chapter, so attention here will only be drawn to what the program demonstrated. Most notable was the reentry procedure practiced with Zond 6 and 7 wherein the spaceship entered the Earth's atmosphere, skipped out to cool the heat shield, and then reentered for landing. This required a great deal of navigation and guidance control.

Concerning life support systems, Oberg reports that without the orbital module, only a single-pilot, six-day mission was possible.[20] This would be enough for a circumlunar flight, although not a landing. It does seem possible, then, that the Soviets could have sent a man at least around the Moon, although since no attempt has been made yet, the case cannot be proven.

3. The Launch Vehicle

The development of a launch vehicle capable of sending a payload heavy enough to accommodate men to the Moon is a hotly debated issue in the West. Some say there is no such vehicle; others say it has been tested.

The D class (or Proton) vehicle is the largest known launch vehicle available to the Russians and has been used for the Salyut space stations, the Zond series, unmanned lunar and planetary landing programs, and at least one Kosmos satellite possibly related to the Moon program (Kosmos 382). But for unknown reasons the vehicle has yet to be man-rated. Since it is possible that the D class is either part of the larger booster or at least its forerunner, its lack of total success could be the major factor preventing the Russians from developing a booster comparable to the American Saturn V.

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[20] Oberg, James E. The hidden history of the Soyuz project. Spaceflight, London, v. 17, August–September 1975 : 284.

The large vehicle, here designated the G–1–e, was first brought to public attention in America in 1967 when NASA representatives began testifying before Congress that the Soviet Union was developing a vehicle with thrust greater than that of Saturn V. Newsmen revealed that outside the hearing room NASA information was more specific: the thrust was in the 5–7 million kilogram range.

To date, no successful test of the G–1–e has been conducted. There are rumors that in the first test (1969) the vehicle blew up on the pad. Vick reports that the explosion was so great that the Nimbus weather satellite observed it and 18 months were required for rebuilding the launch facility.[21] Subsequent countdowns and tests of the vehicle also failed.

Without a vehicle equivalent to Saturn V, a lunar landing was not likely. With tests of the G–1–e beginning in 1969, there is a possibility that the Russians either hoped to send men to the Moon before the scheduled Apollo landing (although this would have allowed little if any time for unmanned tests, their *modus operandi*) or expected the American program to be delayed, perhaps just enough to give them the extra time needed. Some American experts felt the Apollo timetable would slip by as much as a few years, so the Russians had some basis for their hopes.

C. CONCLUSION

Taking into account not only statements by Soviet officials, but the early progress of their space program, evidence seems to support the view that the Russians were indeed aiming for the Moon as much as, if not more than, the Americans. In addition to what has been discussed above, other indicators such as tracking and water recovery exercises are available. The death of Komarov in 1967 and repeated failures of the G–1–e caused severe setbacks in their ambitions, however, and they lost the race.

A further discussion of this issue, as well as the current status of the Russians' lunar landing plans, is given in Chapter Seven.

V. Unmanned Biological Flights

A. KOSMOS 110

At the time of the Voskhod flights, a number of statements were made indicating that further manned flights would occur. One can only speculate whether fiscal economies led to a cancellation of these missions, or whether it was decided to apply the existing stock of launch vehicles to other programs while engineering a later generation manned ship. But apparently at least one more Voskhod flew, only it was unmanned.

Designated Kosmos 110, it was launched on February 22, 1966 into a 904 x 187 km orbit by an A–2 vehicle and carried two dogs, Veterok and Ugolek. A television monitor was on board to add to telemetry from biological and cabin environment sensors. The flight set a duration record of 22 days, following which the dogs were successfully recovered. Data from this mission considerably expanded Soviet information on the more prolonged effects of weightlessness and radiation.

[21] Vick, Charles P. Soviet Superboosters-2. Spaceflight. London, v. 16, March 1974: 96.

B. KOSMOS 605

After a seven year hiatus, the Soviet Union launched another biological satellite, although it is unclear whether a Vostok or Soyuz was used. A Soviet picture not published in the West seems to show a Vostok derivative. Kosmos 605 was launched from Plesetsk by an A–2 vehicle on October 31, 1973 into a 424 x 221 km orbit, inclined at 62.8°, with a period of 90.7 minutes. Aboard the vehicle was a cargo of several dozen white rats, six boxes of steppe tortoises, a colony of Drosophila fruit flies, flour beetles, a mushroom bed and cultures of living bacteriological spores. A control package was kept on Earth during the 21 day space flight, with the only difference in conditions being the gravitational factor.

A. Burnazyan, Deputy Health Minister of the Soviet Union, described the purpose of the mission as "to investigate what functions and processes at the cellular level of the organization of living systems are particularly sensitive to the action of weightlessness and space radiation, and how substantial an effect these can have on the functioning of the organism as a whole." [22]

The condition of the animals was assessed by the amount of motor activity exhibited. This was measured by a special electric monitoring system which used the animals as cores in a weak magnetic field inside their cages. The amount of movement was registered every two hours and telemetered to Earth.

After recovery of the spacecraft, equal numbers of space and control specimens were subjected to autopsy at various time intervals. Some were examined immediately after the flight, others were kept up to 30 days, and still other were kept for prolonged study. A detailed discussion of the results of this mission are given in Chapter Four.

C. KOSMOS 690

A year after Kosmos 605, the Russians launched another mission dedicated to biological research. Again carrying white rats, turtles, Drosophila, lower fungi and microorganisms, Kosmos 690 was placed into a 389 x 223 km orbit inclined at 62.8° with an A–2 vehicle on October 22, 1974.

The primary purpose of this mission, unlike Kosmos 605, was to study the effects of stronger radiation on animals and plants in space. For this, a cesium 137 gamma-ray source was used to dose the rats with 200–1000 rad daily on command from Earth (1,200–1,300 rad is lethal).

After recovery on November 12, the space rats were not only less active than their controls, but they had developed hemorrhages in the lungs. Scientists concluded that exposure to radiation in space has a much greater effect than on Earth. A more detailed discussion of the biological aspects of this mission is in Chapter Four.

D. KOSMOS 782

Pursuant to an agreement between the two countries, the Soviet Union included U.S. experiments on the next in their series of biosats.

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[22] Pravda, Moscow, Nov. 9, 1973, p. 3.

Experiments were also conducted by specialists from Czechoslovakia, France, Hungary, Romania and Poland. The spacecraft, Kosmos 782, was launched from Plesetsk on November 25, 1975 into a 405 x 227 km orbit, inclined at 62.8° with a period of 90.5 minutes.

As a special feature, Kosmos 782 carried a centrifuge to study effects of gravity on living organisms in space. Identical specimens were placed on the centrifuge and off it for comparison purposes. One joint US/USSR experiment studied the growth of cancer cells following up on a discovery by American scientists that the greater the force of gravity, the slower the rate at which cancer cells grow. Czechoslovakia provided a number of white rats for studying the overall effect of spaceflight on organisms, and a French/Romanian/Soviet experiment studied cosmic ray influences on organisms and seeds.

Another joint US/USSR experiment was to study cosmic effects on the aging process in Drosophila which reproduce so rapidly that several generations can be studied on one space flight. Other U.S. experiments included: effects of prolonged weightlessness on plant systems, using carrot slices; detection of heavy particle radiation at different locations aboard the spaceship; and the effects of weightlessness on vestibular systems of killifish.

The Russians invited American scientists to participate in analysis of several of their experiments, including: stress reactions of animals during space flight; effects of weightlessness on the life span of red blood cells, hormonal content of the pituitary gland, and bone tissue development; and possible damage to the retina from high energy particle radiation.

Kosmos 782 landed on December 15, after 19.5 days in space. The mission had originally been scheduled for 22 days, but snowstorms in the recovery area forced an early end to the flight. The Russians announced that for the first time, a set of post-flight experiments were conducted at the landing site using a mobile field laboratory. Preliminary analysis of the NASA experiments indicates that the program went very well. Shortly before the mission had been launched, NASA was invited to include experiments on the next biosat as well, to be launched in 1977. NASA officials seemed pleased to have an opportunity to continue such tests, since they will have to wait until the space shuttle is ready before they can conduct their own biology experiments in space.

E. SOYUZ 20

After termination of the Soyuz 18 mission, Salyut 4 remained in orbit, prompting speculation that a third crew might be sent to work on the space station. This would have been a new feat, since the lifetimes of the Salyut 1 and 3 were limited, and each actually hosted only one crew.

On November 17, 1975 the Russians did indeed launch another Soyuz mission to dock with Salyut 4, but surprisingly this was unmanned. Since during the Soyuz 15 mission the Russians had indicated that they were developing a tanker spacecraft to refuel space stations in orbit, preliminary speculation centered around the possibility that Soyuz 20 was the first such mission. There were many doubts, however, since there was no indication that the Salyut was equipped with a docking port on the service module end, assumed a necessity for fuel trans-

fer. All speculation ended, however, when Soviet ASTP technical director Konstantin Bushuyev, on a post-ASTP visit to Houston, stated that it definitely was not a refueling mission. He said only that the craft would conduct automatic rendezvous and docking tests and check out modifications to the Soyuz for that purpose. A few days later, on December 4, the Russians announced that Soyuz 20 was carrying out parallel biological studies with Kosmos 782. Aboard Soyuz 20, were turtles, Drosophila, cactuses, gladioli bulbs, vegetable seeds, corn and legumes. Soyuz 20 and Kosmos 782 had different microclimates for the specimens aboard, so comparison studies could be performed.

VI. The Soviet Cosmonauts

The biographical information provided here is the latest available, although there is uncertainty as to whether all of it is current, for such data are difficult to obtain. For example, some of the cosmonauts may have been promoted in rank, completed studies, or added to their families without further public announcement.

It is likely that the cosmonauts were chosen in groups as the American astronauts were, although members of such groups generally become known only after they have flown a space mission. Just as many astronauts have yet to fly in space for reasons such as no flight opportunities, leaving the program for personal reasons, or death in non-space accidents, the same is probably true of the Soviet corps. Hence its total dimensions over the entire period since 1960 can only be estimated. A table of the probable dimensions of the corps follows (based generally on the research of James E. Oberg, *Flight International*, August 16, 1973):

Group	Year	Category	Est. Total	Flown	Name and Year of First Flight
1	1960	Pilots	12–20	12	Gagarin 61, Titov 61, Nikolayev 62, Popovich 62, Bykovskiy 63, Komarov 64, Belyayev 65, Leonov 65, Volynov 69, Khrunov 69, Shonin 69, Gorbatko 69.
2	1961	Women	2–4	1	Tereshkova 63.
3	1963–4	Test Pilots	7–10	7	Beregovoy 68, Shatalov 69, Filipchenko 69, Dobrovolskiy 71, Lazarev 73, Artyukhin 74, Gubarev 75.
4	1964	Technicians	3–6	3	Feoktistov 64, Yegorov 64, Demin 74.
5	1965	Pilots	2–4	2	Klimuk 73, Sarafanov 74.
6	1966–7	Engineers	8–12	8	Yeliseyev 69, Kubasov 69, Volkov 69, Sevastyanov 70, Rukavishnikov 71, Patsayev 71, Makarov 73, Grechko 75.
7	1968–9	Scientists?	0–12	0	
8	1970	Pilots	2–6	0	Dzhanibekov ( ), Romanenko ( ).
9	1970	Engineers	2–6	0	Andreyev ( ), Ivanchenko ( ).
10	1972	Engineers	2–6	1	Lebedev 73.
Total			40–86	34	

It is unlikely that cosmonauts have been killed in space flights beyond the few names which will follow in this report, because all known flights have recognizable precursor flights, have been matched by advance rumors of impending launch, have required positioning of support ships world-wide, and have sent live television from orbit. To accept the recurring speculative stories of other deaths in flight requires belief in a second, secret launch program using untried hardware, no support ships, and no television from orbit, and in which all crews are always killed. This strains credulity.

The Oberg studies of Soviet still and motion picture films have shown men from the early days who clearly dressed like and acted like known cosmonauts in these same scenes; hence, they may represent men who have yet to fly, others who have been dropped from the program, trainees killed in non-space accidents, or simply instructors and support personnel. In the February 1974 issue of *Spaceflight*, Oberg announced that one of his unidentified cosmonauts was finally identified as Yevgeniy Karpov, then director of the cosmonaut training program.

A. BIOGRAPHIES OF COSMONAUTS

Boris Dmitriyevich Andreyev; civilian; b. 1940, Moscow; married, two children. Graduated from Moscow's Bauman Higher Technical School, joined a design bureau in 1965 and became a cosmonaut in 1970. He was a member of the second backup crew for the Apollo-Soyuz Test Project.

Yuriy Petrovich Artyukhin; Lieutenant Colonel, Red Air Force; b. 1930, Pershutino, near Moscow; married, two children. Attended Serpukhov Air Force Technical School, served in the Air Force for several years, graduated from Zhukovskiy Air Force Engineering Academy (1958), and joined the cosmonaut corps in 1963. He was the flight engineer on Soyuz 14/Salyut 3.

Pavel Ivanovich Belyayev; Lieutenant Colonel, Red Naval Air Force; b. June 26, 1925 Vologda region; d. January 10, 1970 from complications following an operation for stomach ulcers; was married, two children. Attended the Air Force Academy and became a cosmonaut in 1960. He was the command pilot of Voskhod 2.

Georgiy Timofeyevich Beregovoy; Major General, Red Air Force; b. April 15, 1921, Fedorovka, the Ukraine; married, two children. Attended Lugansk Military Air School, graduated from the Red Banner Air Force Academy (1956) and became a cosmonaut in 1964. He was the pilot of Soyuz 3 and it is speculated that he is no longer in active training for future flights.

Valeriy Fedorovich Bykovskiy; Colonel, Red Air Force; b. August 2, 1934, Pavolo-Posad near Moscow; married, one child. Became a cosmonaut in 1960 and attended Zhukovskiy Air Force Engineering Academy, graduating in 1968. He was the backup pilot for Vostok 3, pilot of Vostok 5, and was chief of cosmonaut training for the Apollo-Soyuz mission. It is speculated that he is no longer in training for future flights.

Lev Stepanovich Demin; Colonel, Red Air Force; b. 1926, Moscow; married, two children. Graduated from an Air Force communications school, Zhukovskiy Air Force Engineering Academy (1956), earned a degree as candidate of technical sciences (1963), and joined the cosmonaut corps in 1964. He was the flight engineer on Soyuz 15.

Georgiy Timofeyevich Dobrovolskiy; Lieutenant Colonel, Red Air Force; b. June 1, 1928, Odessa; d. June 29, 1971 during Soyuz 11 reentry; was married, two children. Graduated from the Air Force School at Chuguyevo and became a cosmonaut in 1963. He was the command pilot of Soyuz 11/Salyut 1.

Vladimir Aleksandrovich Dzhanibekov; Major, Red Air Force; b. 1942, South Kazakhstan region; married, two children. Graduated from the Higher Air School as a pilot-engineer (1965) and became a cosmonaut in 1970. He was a member of the second backup crew for the Apollo-Soyuz Test Project.

Konstantin Petrovich Feoktistov; civilian; b. February 26, 1929, Voronezh; married, one child. Graduated from the Bauman Higher Technical School in Moscow with a master of science degree in engineering (1949) and now holds the degree of doctor of technical sciences. He became a cosmonaut in 1964 and was the technical scientist of Voskhod 1. Dr. Feoktistov has since returned to high-level engineering and played a major role in designing the Salyut space stations.

Anatoliy Vasilyevich Filipchenko; Colonel, Red Air Force; b. February 26, 1928, Davydovka village, Voronezh region; married, two children. Graduated from Chuguyev Air Force School, from the Air Force Academy (1961) and became a cosmonaut in 1963. He was backup command pilot on Soyuz 4, command pilot on Soyuz 7, commander of Soyuz 16 and a member of the primary backup crew for the Apollo-Soyuz Test Project.

Yuriy Alekseyevich Gagarin; Colonel, Red Air Force; b. March 9, 1934, Gzhast Region, Smolensk Oblast; d. March 27, 1968 in a crash of a jet trainer;

was married, two children. Attended Air School in Orenberg, Zhukovskiy Air Force Engineering Academy, and became a cosmonaut in 1960. He was the pilot of Vostok 1 (first man in space), and backup pilot for Soyuz 1.

Viktor Vasiliyevich Gorbatko; Colonel, Red Air Force; b. December 3, 1934, Kuban River region, North Caucasus; married, two children. Entered the Bataysk Air Force School near Rostov in 1953, became a cosmonaut in 1960, and graduated from the Zhukovskiy Air Force Engineering Academy (1968). He was the backup pilot for Voskhod 2, backup pilot for Soyuz 5, and pilot of Soyuz 7.

Georgiy Mikhaylovich Grechko; civilian; b. May 25, 1931, Leningrad; married, two children. Graduated from the Leningrad Institute of Mechanics (1955), worked at a design bureau, received a master of technical sciences on the basis of work connected with landing automatic stations on the Moon, and became a cosmonaut in 1967. A leading spacecraft designer, he was the flight engineer for Soyuz 17/Salyut 4.

Aleksey Aleksandrovich Gubarev; Lieutenant Colonel, Red Air Force; b. March 29, 1931, Kuibyshev, on the Volga; married, two children. Graduated from the naval air force school, Gagarin Air Force Academy, and joined the cosmonaut corps in 1963. He was commander of Soyuz 17/Salyut 4.

Aleksandr Sergeyevich Ivanchenkov; civilian; b. 1940, Ivanteyevka, near Moscow; married, one child. Graduated from the Moscow Aviation Institute, joined a design bureau in 1964, and became a cosmonaut in 1970. He was a member of the third backup crew for the Apollo-Soyuz mission.

Yevgeniy Vasilyevich Khrunov; Colonel, Red Air Force; b. September 10, 1933, Prudiy, near Tula; married, one child. Graduated from Batay Military Aviation College (1956), became a cosmonaut in 1960, graduated from the Zhukovskiy Air Force Engineering Academy (1968), and has since earned a master of science degree. He was the backup pilot for Voskhod 2 and the engineer pilot for both Soyuz 4 and 5, transferring from Soyuz 5 to Soyuz 4 during the flight. He has recently coauthored a book, *Man as Operator in Cosmic Flight.*

Petr Il'ich Klimuk; Lieutenant Colonel, Red Air Force; b. July 10, 1942, Komarovka Village, Byelorussia; married, one child. Graduated from the Higher Air Force College in Chernigov (1964), served in the Air Force, and became a cosmonaut in 1965 (at the age of 23). He was the commander of Soyuz 13 and Soyuz 18/Salyut 4, and since 1973 has been a student at the Gagarin Air Force Academy.

Vladimir Milhaylovich Komarov; Engineer Colonel, Red Air Force; b. March 16, 1927, Moscow; d. April 24, 1967 when Soyuz 1's parachutes tangled during descent; was married, two children. Attended Moscow Air Force School, Third Sassov Air Force School, Serov Flying School in Bataisk, and the Zhukovskiy Air Force Engineering Academy, and became a cosmonaut in 1960. He was backup pilot for Vostok 4, command pilot of Voskhod 1, and pilot of Soyuz 1.

Valeriy Nikolayevich Kubasov; civilian; b. January 7, 1935, Vyazniki; married, two children. Graduated as a mechanical engineer for aircraft building from the Moscow Aviation School (1958), received a master of science degree (1968), and joined the cosmonaut corps in 1967. He was the backup technical scientist for Soyuz 5 and flight engineer on Soyuz 6 and the Apollo-Soyuz Test Project.

Vasiliy Grigor'yevich Lazarev; Lieutenant Colonel, Red Air Force; b. February 23, 1928, Altai region of Southern Siberia; married, one child. Received medical degree specializing in aviation medicine (1952), entered the Air Force school in Chuguyev, since 1954 has been an air force flyer, flight instructor, test pilot and flight equipment tester, and in 1966 became a cosmonaut. He was the backup pilot for Soyuz 9, commander of Soyuz 12 and of the April 5, 1975 unsuccessful Soyuz flight.

Valentin Vital'yevich Lebedev; civilian; b. 1942, Moscow; married, one child. Graduated from the Moscow Aviation Institute (1966), worked as an engineer in a design bureau, and became a cosmonaut in 1972. He was the flight engineer on Soyuz 13.

Aleksey Arkhipovich Leonov; Major General, Red Air Force; b. May 20, 1934, Listvayanka, Altay Kray; married, two children. Graduated from Chuguyev Air Force School, the Zhukovskiy Air Force Engineering Academy, and became a cosmonaut in 1960. He was the co-pilot of Voskhod 2 (first man to perform extravehicular activity in space), and command pilot for the Apollo-Soyuz Test Project.

Oleg Grigor'yevich Makarov; civilian; b. 1933, Kalinin region near Moscow; married, one child. Graduated with an engineering degree from Moscow's Higher Technical School (1957), joined a design bureau where he took part in developing the control board of the Vostok spaceship as well as in desiging the Voskhod and Soyuz ships, and became a cosmonaut in 1966. He was the backup flight engineer for Soyuz 9 and flight engineer of Soyuz 12 and the April 5 unsuccessful Soyuz flight.

Andriyan Grigor'yevich Nikolayev; Major General, Red Air Force; b. September 5, 1929, Shorshely, Chuvash Autonomous Republic; married (to cosmonaut Valentina Tereshkova), one child. Graduated as a pilot from an Air Force school (1954), became a cosmonaut in 1960, and graduated from Zhukovskiy Air Force Engineering Academy (1968). He was backup pilot for Vostok 2, pilot of Vostok 3, backup commander for Soyuz 6, 7 and 8, commander of Soyuz 9, and possibly backup commander for Soyuz 16.

Viktor Ivanovich Patsayev; civilian; b. June 19, 1933, Aktybinsk, Kazakstan; d. June 29, 1971 during Soyuz 11 reentry; was married, two children. Graduated from the Penzensk Industrial Institute (1955), joined the cosmonaut corps in 1969, and earned a master of science degree (1971). He was the test engineer on Soyuz 11/Salyut 1.

Pavel Romanovich Popovich; Colonel, Red Air Force; b. October 5, 1930. Uzin, Kiev Oblast; married, two children. Graduated from an industrial technicum (1951), a military aviation school (1954), Zhukovskiy Air Force Engineering Academy (1968) and became a cosmonaut in 1960. He was the pilot of Vostok 4 and commander of Soyuz 15. Col. Popovich has written an autobiographical work, *Takeoff in the Morning.*

Yuriy Viktorovich Romanenko; Major, Red Air Force; b. 1944, Orenburg Region; married, one child. Graduated from the Higher Air Force School as a pilot-engineer (1966), and became a cosmonaut in 1970. He was a member of the third backup crew for the Apollo-Soyuz Test Project.

Nikolay Nikolayevich Rukavishnikov; civilian; b. September 18, 1932, Tomsk, Siberia; married, one child. Graduated from the Moscow Engineering and Physics Institute (1957), and joined the cosmonaut corps in 1967. He was the test engineer for Soyuz 10, flight engineer for Soyuz 16, and a member of the first backup crew for the Apollo-Soyuz Test Project.

Gennadiy Vasilyevich Sarafanov; Lieutenant Colonel; b. January 1, 1942 near Saratov; married, two children. Graduated from the Balashov Higher Air Force Flying School, served in various air units, and became a cosmonaut in 1965. He was the commander of Soyuz 15.

Vitaliy Ivanovich Sevastyanov; civilian; b. July 8, 1935. Krasnouralsk, Sverdlovsk region; married one child. Graduated from the Moscow Aviation Institute (1959), earned a master of science degree in engineering from the Institute (1965), and became a cosmonaut in 1967. He was the flight engineer on Soyuz 9 and Soyuz 18/Salyut 4.

Vladimir Aleksandrovich Shatalov; Lieutenant General, Red Air Force; b. December 8, 1927, Petropavlosk, Kazakhstan; married, two children. Graduated from the Kachinsk Air Force College (1949), enrolled in the Air Force Academy in Moscow in 1953, and became a cosmonaut in 1963. He was the backup pilot of Soyuz 3, command pilot of Soyuz 4, commander of Soyuz 8 and Soyuz 10. Gen. Shatalov is currently the Cosmonaut Corps Director of Flight Training.

Georgiy Stepanovich Shonin; Colonel, Red Air Force; b. August 3, 1935, Rovenki, the Ukraine; married, two children. Attended Naval Air Force College, Zhukovskiy Air Force Engineering Academy, and became a cosmonaut in 1960. He was backup commander for Soyuz 5 and commander of Soyuz 6.

Valentina Vladimorovna Tereshkova; Engineer Colonel, Red Air Force; b. March 6, 1937, Maslennikovo, Yaroslavl region; married (to Cosmonaut Andriyan Nikolayev), one child. Graduated from a textile technical school. She was the pilot of Vostok 6 and is the only woman to have flown in space.

German Stepanovich Titov; Colonel, Red Air Force; b. September 11, 1935, Verkhneye Zhilino, Kosikha Rayon, Altay Kray; married, two children. Graduated from Volgograd Military Aviation College (1957) and became a cosmonaut in 1960. He was the backup pilot for Vostok 1 and pilot for Vostok 2. In 1968 Col. Titov graduated from the Zhukovskiy Air Force Engineering Academy, and is currently Assistant to the Chief Editor of the Journal of Aviation and Cosmonautics.

Vladislav Nikolayevich Volkov; civilian; b. November 23, 1935, Moscow; d. June 29, 1971 during Soyuz 11 reentry; was married, one child. Entered Moscow Aviation Institute in 1953, worked as an engineer, and became a cosmonaut in 1967. He was the flight engineer on Soyuz 7, and flight engineer on Soyuz 11/Salyut 1.

Boris Valentinovich Volynov; Colonel, Red Air Air Force; b. December 18, 1934, Irkutsk, Siberia; married, two children. Attended Zhukovskiy Air Force Engineering Academy, and became a cosmonaut in 1960. He was the backup pilot for Vostok 5, backup command pilot for Voskhod 1, backup pilot for Soyuz 3, and command pilot of Soyuz 5.

Boris Borisovich Yegorov; Medical Lieutenant, Red Air Force; b. November 26, 1937, Moscow; married, one child. Graduated from the First Medical Institute in Moscow (1961), became a cosmonaut in 1964, received a Doctor of Medicine degree from the Humboldt University of Berlin (1965), and became a candidate of medical sciences in 1967. He was the physiologist for Voskhod 1, after which he returned to medicine and is no longer in training for future flights.

Aleksey Stanislovovich Yeliseyev; civilian; b. July 13, 1934, Zhizdra; married, one child. Attended Bauman Technical High School in Moscow, received master of technical science degree in engineering, and became a cosmonaut in 1966. He was the technical scientist for Soyuz 5 and 4, transferring in flight from Soyuz 5 to Soyuz 4, technical scientist for Soyuz 8 and Soyuz 10, and was the Russian flight director for the Apollo-Soyuz Test Project.

TABLE 3-3.—SUMMARY LIST OF SOVIET COSMONAUTS

Name	Service/Rank	Flights	Comments
Andreyev	Civilian		
Artyukhin	AF/Lt. Col	Soyuz 14/Salyut 3	
Belyayev	Nav. AF/Col	Voskhod 2	Died of complications following an operation for stomach ulcers.
Beregovoy	AF/Maj. Gen	Soyuz 3	Probably no longer in active training.
Bykovskiy	AF/Col	Vostok 5	Probably no longer in active training.
Demin	AF/Col	Soyuz 15	
Dobrovolskiy	AF/Lt. Col	Soyuz 11/Salyut 1	Killed during reentry.
Dzhanibekov	AF/Major		
Feoktistov	Civilian	Voskhod 1	Returned to high level design engineering.
Filipchenko	AF/Col	Soyuz 7, Soyuz 16	
Gagarin	AF/Col	Vostok 1	First man in space. Killed in crash of a jet trainer.
Gorbatko	AF/Col	Soyuz 7	
Grechko	Civilian	Soyuz 17/Salyut 4	
Gubarev	AF/Lt. Col	Soyuz 17/Salyut 4	
Ivanchenkov	Civilian		
Khrunov	AF/Col	Soyuz 4/Soyuz 5	
Klimuk	AF/Lt. Col	Soyuz 13, Soyuz 18/Salyut 4.	
Komarov	AF/Eng. Col	Voskhod 1, Soyuz 1	Killed in Soyuz 1 reentry.
Kubasov	Civilian	Soyuz 6, Soyuz 19 (ASTP).	
Lazarev	AF/Lt. Col	Soyuz 12, April 5 Anomaly.	
Lebedev	Civilian	Soyuz 13.	
Leonov	AF/Maj. Gen	Voskhod 2, Soyuz 19 (ASTP)	First man to perform extravehicular activity in space.
Makarov	Civilian	Soyuz 12, April 5 Anomaly.	
Nikolayev	AF/Maj. Gen	Vostok 3, Soyuz 9	
Patsayev	Civilian	Soyuz 11/Salyut 1	Killed during reentry.
Popovich	Civilian	Vostok 4, Soyuz 14/Salyut 3.	
Romanenko	AF/Capt.		
Rukavishnikov	Civilian	Soyuz 10, Soyuz 16.	
Sarafanov	AF/Col	Soyuz 15.	
Sevastyanov	Civilian	Soyuz 9, Soyuz 18.	
Shatalov	AF/Lt. Gen	Soyuz 4, Soyuz 8, Soyuz 10.	Currently Cosmonaut Corps Director of Flight Training.
Shonin	AF/Col	Soyuz 6.	
Tereshkova	AF/Eng. Col	Vostok 6	Only woman to have flown in space.
Titov	AF/Col	Vostok 2	Currently Assistant to the Chief Editor, Journal of Aviation and Cosmonautics.
Volkov	Civilian	Soyuz 7, Soyuz 11/Salyut 1.	Killed during reentry.
Volynov	AF/Col	Soyuz 5.	
Yegorov	AF/Med. Lt	Voskhod 1	Returned to medicine; no longer in active training for future flights.
Yeliseyev	Civilian	Soyuz 4/Soyuz 5, Soyuz 8, Soyuz 10.	

SOURCE: Tass bulletins.

VII. Statistical Tables on Manned Space Flight

The first table (3–4) on the following pages compares the manned spaceflights of the United States and the Soviet Union. The table is set up in chronological order with the name of the spacecraft in the left column together with its popular label or call sign, if any. The next columns give the launch date, the crew, the payload weight in kilograms, the flight duration, and the national cumulative man hours. The figures for the national cumulative man hours are computed by taking the cumulative man hours through the previous flight of the same country and adding the additional man hours of the new flight. If there was more than one man on the flight, the flight time is multiplied by the number of men. The last column gives the highlights of the different missions.

The second table (3–5) is more detailed, covering just the Soviet flights, but including the precursor missions and other biomedical payloads of principal significance. The number of orbits and revolutions is provided, as well as names of crew members with their rank (if any) and age at time of flight.

The third table (3–6) lists the primary and backup crew members of the various manned spaceflights by program.

The fourth set of tables (3–7 and 3–8) compares the various manned flight programs by number of flights, number of men, and man hours; and reconciles the count of 41 U.S. astronauts who have made 31 flights and the Soviet cosmonauts who have made 27 flights.

The fifth table (3–9) lists the comparative time spent on space missions by astronauts and cosmonauts.

The sixth and final table (3–10) lists the astronauts and cosmonauts who have died either in the program or after leaving it, date, and cause of death.

TABLE 3-4.—U.S. AND U.S.S.R. MANNED SPACEFLIGHTS

Name of Spacecraft	Launch Date	Crew	Payload Weight (kg)	Flight Time (hrs.:min.)	National Cumulative Man Hours (hrs.:min.)	Highlights
		1961				
Vostok 1, Kedr (Cedar)	Apr. 12	Gagarin	4,725	1:48	1:48	First manned flight
Mercury-Redstone 3, Freedom 7	May 5	Shepard	1,290	:15	:15	First U.S. flight; suborbital
Mercury-Redstone 4, Liberty Bell 7	July 21	Grissom	1,286	:16	:31	Suborbital; capsule sank after landing
Vostok 2, Oryel (Eagle)	Aug. 6	Titov	4,731	25:18	27:06	First flight exceeding 24 hours
		1962				
Mercury-Atlas 6, Friendship 7	Feb. 20	Glenn	1,355	4:55	5:26	First American to orbit
Mercury-Atlas 7, Aurora 7	May 24	Carpenter	1,349	4:56	10:22	Landed 250 miles (402 km) from target
Vostok 3, Sokol (Falcon)	Aug. 11	Nikolayev	4,722	94:22	121:28	First dual mission
Vostok 4, Berkut (Golden Eagle)	Aug. 12	Popovich	4,728	70:57	192:25	In near co-orbit, made pass at 4 miles (6.5 km); sometimes considered first rendezvous
Mercury-Atlas 8, Sigma 7	Oct. 3	Schirra	1,373	9:13	19:35	Landed 5 miles (8 km) from target
		1963				
Mercury-Atlas 9, Faith 7	May 15	Cooper	1,376	34:20	53:55	First U.S. flight exceeding 24 hours
Vostok 5, Yastreb (Hawk)	June 14	Bykovskiy	4,720	119:06	311:31	Second dual mission
Vostok 6, Chayka (Sea Gull)	June 16	Tereshkova	4,713	70:50	382:21	First woman to orbit. Made pass at 3 miles (5 km).
		1964				
Voskhod 1, Rubin (Ruby)	Oct. 12	Komarov, Yegorov, Feoktistov	5,320	24:17	455:12	First three man crew
		1965				
Voskhod 2, Almaz (Diamond)	Mar. 18	Belyayev, Leonov	5,682	26:02	507:16	First extravehicular activity (EVA)—Leonov
Gemini-Titan 3, Molly Brown	Mar. 23	Grissom (2), Young	3,225	4:53	63:41	First U.S. 2 man crew; first manual maneuvers in space
Gemini-Titan 4	June 3	McDivitt, White	3,574	97:56	259:33	First U.S. EVA—White
Gemini-Titan 5	Aug. 21	Cooper (2), Conrad	3,605	190:55	641:23	Longest duration manned flight to date; performed phantom rendezvous
Gemini-Titan 7	Dec. 4	Borman, Lovell	3,663	330:35	1,302:33	Longest duration manned flight to date; target for rendezvous
Gemini-Titan 6	Dec. 15	Schirra (2), Stafford	3,546	25:51	1,354:15	Rendezvous within 1 foot (30 cm) of Gemini 7 and conducted sustained co-orbit
		1966				
Gemini-Titan 8	Mar. 16	Armstrong, Scott	3,788	10:41	1,375:37	Rendezvous and first docking of 2 orbiting spacecraf (with Agena 8 target). Emergency recovery after developing high rate of spin
Gemini-Titan 9	June 3	Stafford (2), Cernan	3,750	72:21	1,520:19	EVA—Cernan (2 hrs. 07 min.) Rendezvous performed 3 times but no docking because shroud not jettisoned on target.

Gemini-Titan 10	July 18	Young (2), Collins	3,741	70:47	1,661:53	First dual rendezvous (with Agena 8 target and Agena 10 target); 2 EVA—Collins; Retrieved by EVA an experiment on Agena 8 target. Used target as propulsion unit following docking
Gemini-Titan 11	Sept. 12	Conrad (2), Gordon	3,860	71:17	1,804:27	First initial orbit rendezvous; first tethered flight; highest Earth orbit to date (853 miles) (1,372 km) conducted; EVA—Gordon (44 min). 2 rendezvous and 4 dockings
Gemini-Titan 12	Nov. 11	Lovell (2), Aldrin	3,763	94:35	1,993:37	Longest EVA; Rendezvous and 3 dockings; total 3 EVA (Aldrin—5 hrs., 37 min.)
		1967				
(Apollo 4) (AS 204)	Jan. 27	Grissom (3), White (2), Chaffee	20,412	[Not a space flight, but date of fatal fire on pad during test preliminary to later scheduled flight]		All 3 astronauts asphyxiated; the capsule was damaged, but the launch vehicle was unbarmed and later flew unmanned as Apollo 5.
Soyuz 1 Rubin (Ruby)	Apr. 23	Komarov (2)	6,450	26:37	533:53	First man killed in space flight—parachutes tangled in landing
		1968				
Apollo-Saturn 205, Apollo 7	Oct. 11	Schirra (3), Eisele, Cunningham	20,569	260:09	2,744:04	First U.S. 3-man mission. Rendezvous with 3rd stage
Soyuz 3, Argon (Argon)	Oct. 26	Beregovoy	6,575	94:51	628:44	Maneuvered to rendezvous near unmanned Soyuz 2
Apollo-Saturn 503, Apollo 8	Dec. 21	Borman (2), Lovell (3), Anders	43,663	147:01	3,215:07	First manned orbits of the Moon; first manned departure from Earth's sphere of influence; highest speed on manned flight
		1969				
Soyuz 4, Amur	Jan. 14	Shatalov (Khrunov) (Yeliseyev)	6,625	71:23	795:45	Rendezvous and first docking of two manned ships. First receipt of crew from another ship
Soyuz 5, Baykal	Jan. 15	Volynov, Khrunov, Yeliseyev	6,585	72:56	868:41	First transfer of crew to another ship; target for rendezvous and docking
Apollo-Saturn 504, Apollo 9, Gumdrop and Spider	Mar. 3	McDivitt (2), Scott (2), Schweickart	43,136	241:01	3,938:10	Tested the propulsion, rendezvous, and docking capabilities of the lunar excursion module
Apollo-Saturn 505, Apollo 10, Charlie Brown and Snoopy	May 18	Stafford (3), Young (3), Cernan (2)	48,638	192:03	4,514:19	Testing of lunar excursion module in lunar orbit
Apollo-Saturn 506, Apollo 11, Columbia and Eagle	July 16	Armstrong (2), Collins (2), Aldrin	49,698	195:19	5,100:16	Landed on Moon and returned safely
Soyuz 6, Antey (Antaeus)	Oct. 11	Shonin, Kubasov	6,577	118:42	1,106:05	Tested welding in space rendezvous with Soyuz 7
Soyuz 7, Buran (Snowstorm)	Oct. 12	Filipchenko, Volkov, Gorbatko	6,570	118:41	1,462:08	Earth resources survey, rendezvous target.
Soyuz 8, Granit (Granite)	Oct. 13	Shatalov (2), Yeliseyev (2)	6,646	118:50	1,699:48	Earth resources survey, rendezvous with Soyuz 7
Apollo-Saturn 507, Apollo 12, Yankee Clipper, and Intrepid	Nov. 14	Conrad (3), Gordon (2), Bean	49,804	244:36	5,834:04	2nd lunar landing; returned safely.
		1970				
Apollo-Saturn 508, Apollo 13, Odyssey and Aquarius	Apr. 11	Lovell (4), Swigert, Haise	49,990	142:55	6,262:49	3rd lunar landing attempt aborted due to explosion in service module
Soyuz 9, Sokol (Falcon)	June 1	Nikolayev (2), Sevastyanov	6,500	424:59	2,549:46	Duration record of 17 days 16 hours 59 minutes for medical purposes
		1971				
Apollo-Saturn 509, Apollo 14, Kitty Hawk and Antares	Jan. 31	Shepard (2), Roosa, Mitchell	46,346	216:02	6,910:55	3rd lunar landing; returned safely

TABLE 3-4.—U.S. AND U.S.S.R. MANNED SPACEFIGHTS—Continued

Name of Spacecraft	Launch Date	Crew	Payload Weight (kg)	Flight Time (hrs.:min.)	National. Cumulative Man Hours (hrs.:min.)	Highlights
Salyut 1	Apr. 19		18, 596?			Launched unmanned, docking target for Soyuz 10 and 11
Soyuz 10, Granit (Granite)	Apr. 22	Shatalov (3), Yeliseyev (3), Rukavishnikov	6, 575?	47:46	2, 693:04	First crew to dock with Salyut space station, but no transfer into station.
Soyuz 11, Yantar (Amber)	June 6	Dobrovolskiy, Patseyev, Vokov (2)	6, 575?	570:22	4, 404:10	2nd crew to reach Salyut space station, 1st to enter it. Set duration record of 23 days 18 hrs. 22 min. Killed upon reentry due to depressurization of spacecraft.
Apollo-Saturn 510, Apollo 15, Endeavor and Falcon.	July 26	Scott (3), Worden, Irwin	52, 759	295:12	7, 796:31	4th lunar landing: returned safely, 1st men to drive on Moon (lunar rover vehicle)
		1972				
Apollo-Saturn 511, Apollo 16, Casper and Orion.	Apr. 16	Young (4), Mattingly, Duke	51, 571	265:51	8, 594:04	5th lunar landing; returned safely. 2nd men to drive on Moon (lunar rover vehicle).
Apollo-Saturn 512, Apollo 17, America and Challenger.	Dec. 7	Cernan (3), Evans, Schmitt	51, 808	301:52	9, 499:40	6th lunar landing; returned safely. Last manned Moon landing of the Apollo program. Used lunar roving vehicle.
		1973				
Skylab 1, Apollo-Saturn 513 with Apollo-Saturn 212.	May 14		74, 783			Launched unmanned for later use by crews of SL-2, 3, 4.
Skylab 2, Apollo-Saturn 206, CSM 116	May 25	Conrad (4), Kerwin, Weitz	13, 978	672:50	11, 518:10	Crew repaired damage to and occupied Skylab 1.
Skylab 3, Apollo-Saturn 207, CSM 117	July 28	Bean (3), Garriott, Lousma	14, 167	1, 427:09	15, 799:37	Crew made further repairs to and occupied Skylab 1.
Soyuz 12, Uraliy (Urals)	Sept. 27	Lazarev, Makarov	6, 575?	47:16	4, 498:42	Checkout of engineering fixes.
Skylab 4, Apollo-Saturn 208, CSM 118	Nov. 11	Carr, Gibson, Pogue	14, 900	2, 017:16	21, 851:25	Occupied Skylab 1 and set world duration record.
Soyuz 13, Kavkaz (Caucasus)	Dec. 18	Klimuk, Lebedev	6, 575?	188:55	4, 876:32	Astrophysical biological and earth resources experiments.
		1974				
Salyut 3	June 24		18, 500?			Unmanned docking target for Soyuz 14 and 15.
Soyuz 14, Berkut (Golden Eagle)	July 3	Popovich (2), Artyukhin	6, 570?	377:30	5, 631:32	Occupied Salyut 3.
Soyuz 15 Dunay (Danube)	Aug. 26	Sarafanov, Demin	6, 570?	48:12	5, 727:56	Unsuccessful attempt to dock with Salyut 3.
Soyuz 16, Buran (Snowstorm)	Dec. 2	Filipchenko (2), Rukavishnikov (2)	6, 570?	142:24	6, 012:44	ASTP precursor flight to check out new designs for Soyuz craft.
Salyut 4	Dec. 26		18, 500?			Unmanned docking target for Soyuz 17 and 18.
		1975				
Soyuz 17, Zenit (Zenith)	Jan. 10	Grechko, Gubarev	6, 570?	709:20	7, 431:24	Occupied Salyut 4.
April 5 Anomaly Uraliy (Urals)	Apr. 5	Lazarev (2), Makarov (2)	6, 570?	:20	7, 432:04	Mission aborted before reaching orbit due to third stage malfunction; intended to dock with Salyut 4.
Soyuz 18, Kavkaz (Caucasus)	May 24	Klimuk (2), Sevastyanov (2)	6, 800?	1, 511:20	10, 454:44	Occupied Salyut 4.
Soyuz 19, Soyuz (Union)	July 15	Leonov (2), Kubasov (2)	6, 800	142:31	10, 739:46	First link-up in space between ships from different nations.
Apollo-Soyuz	July 15	Stafford (4), Brand, Slayton	14, 743	217:28	22, 503:49	First link-up in space between ships from different nations.

SOURCE: TASS bulletins and NASA press releases.

TABLE 3-5.—SOVIET FLIGHTS RELATED TO BIOLOGICAL PAYLOADS

Name of Spacecraft	Launch Date	Weight (kg)	Apogee (km)	Perigee (km)	Inclination	Period	Orbits	Revolutions	Remarks
						1957			
Sputnik 2	Nov. 3	508	1,671	225	65.3	103.7	100	93	No recovery attempted. Dog Layka poisoned after 1 week.
						1960			
Korabl Sputnik 1	May 15	4,540	369	312	65.0	91.2	48	44	Recovery failed. Cabin entered higher orbit, decayed Oct. 15, 1965. Carried robot only.
Korabl Sputnik 2	Aug. 18	4,600	339	306	65.0	90.7	17	16	Recovered. Dogs Strelka and Belka.
Korabl Sputnik 3	Dec. 1	4,563	265	187	65.0	88.6	17	16	Recovery failed. Dogs Pchelka and Mushka burned on reentry.
						1961			
Korabl Sputnik 4	Mar. 9	4,700	249	184	64.9	88.5	1	1	Recovered. Dog Chernushka.
Korabl Sputnik 5	Mar. 25	4,695	247	178	64.9	88.4	1	1	Recovered. Dog Zvezdochka.
Vostok 1 Kedr (Cedar)	Apr. 12	4,725	327	181	65.0	89.1	1	1	Recovered. Major Yuriy Gagarin, 27,
Vostok 2 Oryel (Eagle)	Aug. 6	4,731	257	178	64.9	88.6	17	16	Recovered Maj. German Titov, 26.
						1962			
Vostok 3 Sokol (Falcon)	Aug. 11	4,722	251	183	65.0	88.5	64	60	Recovered. Maj. Andriyan Nikolayev, 32.
Vostok 4 Berkut (Golden Eagle).	Aug. 12	4,728	254	180	65.0	88.5	48	45	Performed near coorbit at 6.5 km. Recovered. Lt. Col. Pavel Popovich, 31.
						1963			
Vostok 5 Yastreb (Hawk)	June 14	4,720	222	175	65.0	88.3	81	76	Recovered. Lt. Col. Valeriy Bykovskiy, 28.
Vostok 6 Chayka (Sea Gull)	June 16	4,713	233	183	65.0	88.3	48	45	Performed near pass at 5 km. Recovered. Lt. Valentina Tereshkova, 26.
						1964			
Kcsmos 47	Oct. 6	5,320	413	177	64.8	90.0	16	15	Probably recovered. Voskhod precursor.
Voskhod 1 Rubin (Ruby)	Oct. 12	5,320	409	178	65.1	90.1	16	15	Recovered. Col. Vladimir Komarov, 37; Lt. Boris Yegorov, 27; Konstantin Feoktistov, 38.
						1965			
Kosmos 57	Feb. 22	5,682?	512	175	64.8	91.1			Probably exploded. Voskhod precursor.
Voskhod 2 Almaz (Diamond).	Mar. 18	5,682	495	173	65.0	90.9	17	16	Recovered. Col. Pavel Belyayev, 39; Lt. Col. Aleksey Leonov, 30. First EVA.
						1966			
Kosmos 110	Feb. 22	5,200?	904	187	51.9	96.3	330	308	Recovered. Dogs Veterok, and Ugolek.
Kosmos 133	Nov. 28	6,575?	232	181	51.8	88.4	33	31	Probably recovered. Soyuz precursor.

TABLE 3-5.—SOVIET FLIGHTS RELATED TO BIOLOGICAL PAYLOADS—Continued

Name of Spacecraft	Launch Date	Weight (kg)	Apogee (km)	Perigee (km)	Inclination	Period	Orbits	Revolutions	Remarks
						1967			
Kosmos 140	Feb. 7	6, 575?	241	170	51.7	88.5	32	30	Probably recovered. Soyuz precursor.
Kosmos 146	Mar. 10	22, 720?	310	190	51.5	89.1	16?	15?	Obscure result. Zond precursor.
Kosmos 154	Apr. 8	22, 720?	232	185	51.6	88.5	35?	33?	Obscure result. Zond precursor.
Soyuz 1 Rubin (Ruby)	Apr. 23	6, 575?	224	201	51.7	88.6	18	17	Recovery failed. Col. Vladimir Komarov, 40, killed when ship parachute lines tangled during reentry.
Kosmos 186	Oct. 27	6, 575?	276	200	51.7	89.0	65	61	Maneuvered from a lower orbit to dock with Kosmos 188 on Oct. 31, then recovered in soft landing. Soyuz precursor.
Kosmos 188	Oct. 30	6, 575?	276	200	51.7	89.0	48	45	Target for docking of Kosmos 186, then later maneuvered, recovered. Soyuz precursor.
						1968			
Zond 4	Mar. 2	22, 720?			51.5				Manned precursor flew out probably beyond the Moon's orbit with obscure results.
Kosmos 212	Apr. 14	6, 577?	292	205	51.4	89.2	80	75	Maneuvered from a lower orbit to dock with Kosmos 213 on Apr. 15, then maneuvered again, and recovered. Soyuz precursor.
Kosmos 213	Apr. 15	6, 575?	292	205	51.4	89.2	81	76	Target for the docking of Kosmos 212, then later maneuvered, recovered. Soyuz precursor.
Kosmos 238	Aug. 28	6, 575?	219	199	51.7	88.5	64	60	Probably recovered. Soyuz precursor.
Zond 5	Sep. 14	22, 720?			51.3				Manned precursor flew around the Moon at a distance of 1,950 km, taking pictures and carrying biological specimens. Recovered in South Indian Ocean after 7 days.
Soyuz 2	Oct. 25	6, 575?	231	185	51.7	88.4	48	45	Target for the rendezvous of Soyuz 3. Recovered in soft landing. Unmanned.
Soyuz 3 Argcn	Oct. 26	6, 557?	252	179	51.7	88.6	64	60	Maneuvered to rendezvous with Soyuz 2, then manuevered again, recovered. Col. Georgiy Beregovoy, 47.
Zond 6	Nov. 10	22, 720?			51.4				Manned precursor flew around Moon at a distance of 2,420 km taking pictures and carrying biological specimens. 7 days after launch approached South Indian Ocean in a ballistic trajectory, but made lifting reentry to fly to Soviet Union where recovery made.
						1969			
Soyuz 4 Amur	Jan. 14	6.625	250	209	51.7	88.9	48	45	Maneuvered from a lower orbit to dock with Soyuz 5. During EVA; gained two crewmembers from the latter ship and after further maneuvers was recovered. Lt. Col. Vladimir Shatalov, 41.
Soyuz 5 Baykal	Jan. 15	6, 585	250	209	51.7	88.9	49	46	Target for the docking of Soyuz 4; gave up 2 crewmembers, then later maneuvered, recovered. Lt. Col. Boris Volynov, 34; Aleksey Yeliseyev, 34; Lt. Col. Yevgeniy Khrunov, 35.
Zond 7	Aug .7	22, 720?			51.5				Manned precursor flew around Moon at approximate distance of 2,000 km. taking pictures. 7 days after launch approached South Indian Ocean in a ballistic trajectory, but made a lifting reentry to fly to the Soviet Union where recovery made.

Soyuz 6 Antey (Antaeus)	Oct. 11	6,577	230	186	51.7	88.6	80	75	Maneuvered to rendezvous with Soyuz 7, but not equipped for docking. Conducted welding experiments and Earth resource surveys. Col. Georgiy Shonin, 34; Valeriy Kubasov, 34.
Soyuz 7 Buran (Snowstorm).	Oct. 12	6,570	226	207	51.7	88.6	80	75	Target for rendezvous of Soyuz 6 and 8. Performed geologic and geographic studies, multispectral studies of Earth resources. Lt. Col. Anatoliy Filipchenko, 41; Lt. Col. Viktor Gorbatko, 35; Vladislav Volkov, 34.
Soyuz 8 Granit (Granite)	Oct. 13	6,646	256	190	51.7	88.9	80	75	Rendezvoused with Soyuz 7 but unknown difficulties prevented docking as planned. Conducted engineering tests and Earth resources surveys. Col. Vladimir Shatalov, 42; Aleksey Yeliseyev, 35.
					1970				
Soyuz 9 Sokol (Falcon)	June 1	6,575?	266	247	51.7	89.5	286	268	Conducted engineering systems tests, biomedical tests, and Earth resources experiments. Set endurance record of 18 days, then recovered. Col. Andriyan Nikolayev, 40; Vitaliy Sevastyanov, 34.
Zond 8	Oct. 20	22,720?			51.5				Manned precursor flew around Moon at a distance of 1,120 km taking pictures, returning live TV. 7 days after launch, approached over Northern hemisphere and made ballistic reentry into Indian Ocean where recovered.
Kosmos 379	Nov. 24	6,575?	253	198	51.6	88.7			Placed in an initial orbit closely reminiscent of a Soyuz. On successive days maneuvered to higher apogees. Precursor activity still obscure in intent.
			1,204		51.7	98.8			
			14,028		51.7	259.8			
Kosmos 382	Dec. 2	22,720?	5,040	320	51.6	143.0			Placed in a new type of initial orbit, then after 3 days raised perigee, and a day later raised perigee again, also with a major plane change. Precursor activity is still obscure.
			5,072	1,615	51.6	158.9			
			5,082	2,577	55.9	171.1			
					1971				
Kosmos 398	Feb. 26	6,575?	276	196	51.6	88.9			After attaining a low orbit, was shifted to higher orbits.
			10,903	203	51.6	216.1			
Salyut 1	Apr. 19	18,600?	317	284	51.5	90.5	2,800?	2,625?	Unmanned station was later joined by Soyuz 10, and then by Soyuz 11 with occupancy. Maneuvered to decay over the Pacific Oct. 11, 1971
Soyuz 10 Granit (Granite)	Apr. 22	6,575?	246	208	51.6	89.0	32	30	Rendezvoused and docked Salyut 1 for 5.5 hours. Col. Vladimir Shatalov, 43; Aleksey Yeliseyev, 36; Nikolay Rukavishnikov, 39. Recovered.
Soyuz 11 Yantar (Amber)	June 6	6,575?	282	259	51.6	89.7	383	359	Rendezvoused and docked with Salyut 1 for 538:43 hours. Occupied station. Lt. Col. Georgiy Dobrovolskiy, 43; Vladislav Volkov, 35; Viktor Paysayev, 38. Crew died during reentry.
Kosmos 434	Aug. 12	6,575?	285	197	51.6	89.0			After attaining a low orbit, was shifted to higher orbit.
			11,804	186	51.6	228.2			
					1972				
Kosmos 496	June 26	6,570	342	195	51.6	89.6	96	90	

TABLE 3-5.–SOVIET FLIGHTS RELATED TO BIOLOGICAL PAYLOADS—Continued

Name of Spacecraft	Launch Date	Weight (kg)	Apogee (km)	Perigee (km)	Inclination	Period	Orbits	Revolutions	Remarks
						1973			
Salyut 2	Apr. 3	18, 600?	260	215	51.6	89.0	885	830	Space station which suffered unknown malfunction, causing it to break apart in orbit.
Kosmos 557	May 11	18, 600?	226	218	51.6	89.1	180	169	Possibly a space station which failed so early in its mission that it was designated a Kosmos instead of Salyut.
Kosmos 573	June 15	6, 570?	329.2	196.2	51.6	89.5	32	30	
Soyuz 12 Uraliy (Urals)	Sep. 27	6, 570?	345	326	51.6	91.0	31	29	Test of engineering fixes after Soyuz 11 tragedy. Recovered. Vasiliy Lazarev, 45; Oleg Makarov, 40.
Kosmos 605	Oct. 31	5, 500?	424	221	62.8	90.7	341	319	Biological mission carried several species of animals and other specimens to test reaction to weightlessness. Recovered after 21 days.
Kosmos 613	Nov. 30	6, 570?	295	195	51.6	89.1	954	934	Systems test of Soyuz craft to determine if it could remain in orbit for 60 days inactive, then be successfully reactivated for return to Earth.
Soyuz 13 Kavkaz (Caucasus)	Dec. 18	6, 570?	272	225	51.6	89.2	127	116	Conducted astrophysical, biological and earth resources experiments. Maj. Petr Klimuk, 31; Valentin Lebedev, 31.
						1974			
Kosmos 638	Apr. 3	6, 570?	325	195	51.8	89.4	160	144	Tests of engineering changes in preparation for the Apollo-Soyuz linkup in 1975.
Kosmos 656	May 27	6, 570?	354	194	51.6	89.7	32	30	Tests of engineering changes in preparation for the Apollo-Soyuz link-up in 1975.
Salyut 3	June 24	18, 600?	276	263	51.6	89.7	3, 470?	3, 256?	Unmanned docking target for Soyuz 14 and 15. Reentered atmosphere over Pacific on Jan. 24, 1975.
Soyuz 14 Berkut (Golden Eagle).	July 3	6, 570?	277	255	51.6	89.7	252	236	Occupied Salyut 3 for 14 days. Reportedly focused on Earth resources photography; may have been military reconnaissance. Col. Pavel Popovich, 43; Lt. Col. Yuriy Artyukhin, 43. Recovered.
Kosmos 670	Aug. 6	6, 570?	307	217	50.6	89.5	48	45	Engineering test of possible Soyuz ferry at new inclination.
Kosmos 672	Aug. 12	6, 570?	239	198	51.8	88.6	96	90	Tests of engineering changes in preparation for the Apollo-Soyuz link-up in 1975.
Soyuz 15 Dunay (Danube)	Aug. 26	6, 570?	275	254	51.6	89.6	32	30	Unsuccessful attempt to dock with Soyuz 3. Lt. Col. Gennadiy Sarafanov, 32; Col. Lev Demin, 48. Recovered after two days.
Kosmos 690	Oct. 22	5, 500?	389	223	62.8	90.4	327?	306?	Biological mission carried white rats to test their reaction to radiation in space. Carried cesium 137 gamma ray source. Recovered after 21 days.
Soyuz 16 Buran (Snow-storm).	Dec. 2	6, 570?	225	225	51.8	88.9	96	90	ASTP precursor to check out new designs for Soyuz craft. Recovered. Col. Anatoliy Filipchenko, 46; Nikolay Rukavishnikov, 42.
Salyut 4	Dec. 26	18, 900?	355	343	51.6	91.3			Unmanned docking target for Soyuz 17 and 18.
						1975			
Soyuz 17 Zenit (Zenith)	Jan. 10	6, 570?	355	342	51.6	91.3	466	426	Occupied Salyut 4, for 30 days. Performed astrophysical and Earth resources experiments. Recovered. Lt. Col. Aleksey Gubarev, 43; Georgiy Grechko, 43.

April 5 Anomaly Uraliy (Urals).	Apr. 5	6,570?			51.6				Mission aborted before reaching orbit due to third stage malfunction; intended to dock with Salyut 4. Successfully recovered in Siberia. Lt. Col. Vasiliy Lazarev, 47; Oleg Makarov, 42.
Soyuz 18 Kavkaz (Caucasus).	May 24	6,570?	356	344	51.6	91.3	993	930	Occupied Salyut 4 for 63 days, performing astrophysical and Earth resources experiments. Recovered. Lt. Col. Petr Klimuk, 32; Vitaliy Sevastyanov, 39.
Soyuz 19 Soyus (Union)	July 15	6,800?	225	225	51.8	88.9	96	90	Docked with American Apollo spacecraft for first link-up in space between ships from different nations. Performed joint as well as individual experiments. Col. Aleksey Leonov, 41; Valeriy Kubasov, 40.
Kosmos 772	Sept. 29	6,570?	320	201	51.8	89.4	48	45	Possible test of new battery capacity or lessened electrical loads perhaps relating to return to three-man crews.
Soyuz 20	Nov. 17	6,570?	367	343	51.6	91.4			Docked with Salyut 4 but carried biological experiments only. Performed parallel studies with Kosmos 782.
Kosmos 782	Nov. 25	5,500?	405	227	62.8	90.5	311?	291?	Carried experiments from U.S., U.S.S.R., Hungary, Poland, France, Romania and Czechoslovakia. Using a centrifuge, conducted experiments on effects of different g-forces on biological specimens.

NOTES

1. This table incorporates all Soviet flights known or suspected as being related to manned or biological programs, including engineering precursor flights.

2 Where a second name is given with a particular flight, this is the radio call sign made available by Soviet news sources, with the English equivalent if different.

3. The weights are as announced by the Russians, or if followed by a question mark have been estimated by analogy. For the deep space flights, the Earth orbital payload weight has been estimated.

4. Orbital parameters are as given by the Russians, except where maneuvers were detected by Western sensors and published by Goddard or the British RAE. The parameters from Soviet sources represent the highest announced, as a number of craft made some orbital adjustments.

5. The number of orbits (typically used by the U.S.S.R.) and number of Earth revolutions (typically used by the United States) are shown either to time of recovery or end of active mission, if known.

SOURCES: As indicated above, from TASS, Goddard satellite situation report, and the British RAE.

TABLE 3-6.—SOVIET CREWS BY PROGRAM

Program	Prime Crew: Command Pilot	Prime Crew: Pilot; (Other)	Prime Crew: Pilot; (Other)	Backup Crew: Command Pilot	Backup Crew: Pilot; (Other)	Backup Crew: Pilot; (Other)
Vostok:						
1	Gagarin			Titov		
2	Titov			Nikolayev		
3	Nikolayev			Bykovskiy		
4	Popovich			Komarov		
5	Bykovskiy			Volynov		
6	Tereshkova			?		
Voskhod:						
1	Komarov	Yegorov (Physiologist)	Feoktistov (Tech. Sci.)	Volynov	?	?
2	Belyayev	Leonov		?	Khrunov, Gorbatko	
Soyuz:						
1	Komarov			Gagarin		
3	Beregovoy			Shatalov		
4	Shatalov	Khrunov (Eng. Pilot)	Yeliseyev (Tech. Sci.)	Filipchenko		
5	Volynov	Khrunov (Eng. Pilot)	Yeliseyev (Tech. Sci.)	Shonin	Gorbatko	Kubasov (Tech. Sci.)
6	Shonin	Kubasov (Flt. Eng.)		Nikolayev	?	
7	Filipchenko	Volkov (Flt. Eng.)	Gorbatko	Nikolayev	?	?
8	Shatalov	Yeliseyev (Tech. Sci.)		Nikolayev	?	
9	Nikolayev	Sevastyanov (Flt. Eng.)		Lazarev	Makarov (Flt. Eng.)	
10	Shatalov	Yeliseyev (Tech. Sci.)	Rukavishnikov (Test Eng.)	?	?	?
11	Dobrovolskiy	Volkov (Flt. Eng.)	Patsayev (Test. Eng.)	?	?	?
12	Lazarev	Makarov (Flt. Eng.)		?	?	
13	Klimuk	Lebedev (Flt. Eng.)		?	?	
14	Popovich	Artyukhin (Flt. Eng.)		?	?	
15	Sarafanov	Demin (Flt. Eng.)		?	?	
16	Filipchenko	Rukavishnikov (Flt. Eng.)		?	?	
17	Gubarev	Greckho (Flt. Eng.)		?	?	
April 5 Anomaly*	Lazarev	Makarov (Flt. Eng.)		?	?	
18	Klimuk	Sevastyanov (Flt. Eng.)		?	?	
19	Leonov	Kubasov (Flt. Eng.)		(2nd) Filipchenko	Rukavishnikov	
				(3rd) Dzhanibekov	Andreyev	
				(4th) Romanenko	Ivanchenkov	

* Mission was aborted before reaching orbit due to third stage malfunction. Although its number would have been 18 if successful, the Soviets designated it the April 5 Anomaly.

SOURCE: TASS bulletins.

TABLE 3-7.—MANNED SPACEFLIGHT PROGRAMS SUMMARIZED (SOVIET)

Flight	Crew size	Flight duration	Man-hours
Vostok:			
1	1	1:48	1:48
2	1	25:18	25:18
3	1	94:22	94:22
4	1	70:57	70:57
5	1	119:06	119:06
6	1	70:50	70:50
Subtotal	6	382:21	382:21
Voskhod:			
1	3	24:17	72:51
2	2	26:02	52:04
Subtotal	5	50:19	124:55
Soyuz:			
1	1	26:37	26:37
3	1	94:51	94:51
4 (Shatalov)	1	71:23	71:23
(Yeliseyev, Khrunov)	2	(47:49)	95:38
5 (Volynov)	1	72:56	72:56
6	2	118:42	237:24
7	3	118:41	356:03
8	2	118:50	237:40
9	2	424:59	849:58
10	3	47:46	143:18
11/Salyut 1	3	570:22	1,711:06
(undocked)		(31:39)	(94:57)
(docked)		(538:43)	(1,616:09)
12	2	47:16	94:32
13	2	188:55	377:50
14/Salyut 3	2	377:30	755:00
(undocked)		(17:27)	(34:54)
(docked)		(360:03)	(720:06)
15	2	48:12	96:24
16	2	142:24	184:48
17/Salyut 4	2	709:20	1,418:40
(undocked)		[1] (33:27)	(66:54)
(docked)		(675:53)	(1,351:46)
April 5 Anomaly	2	:20	:40
18/Salyut 4	2	1,511:20	3,022:40
(undocked)		[2] (30:54)	(61:48)
(docked)		(1,480:26)	(2,960:52)
19	2	142:31	285:02
Subtotal	39	4,832:56	10,232:30
Total (U.S.S.R.)[3]	50	5,295:36	10,739:46

NOTE: Figures in parentheses are subtotals, or would represent elements of double-counting.

[1] TASS, 9 Feb 75, 1225 GMT reported the time of undocking as 0908 Moscow Time (0608 GMT) and this figure is used for this report. However, on 10 Feb 75, Pravda reported the time as 0809 Moscow Time (0509 GMT). The reason for the discrepancy is not known, but could simply have been a typographical error in the Pravda release.

[2] No precise time was given for docking At 1221 Moscow Time (1821 GMT) Soyuz was reportedly 800 meters from the station, so an estimation is made here of 1830 GMT for time of docking.

[3] Breakdown for U.S.S.R.:

	Persons	Number
3 times	2	6
2 times	12	24
1 time	20	20
Total	34	50

SOURCE: TASS bulletins.

TABLE 3-8.—MANNED SPACEFLIGHT PROGRAMS SUMMARIZED (U.S.)

Flight	Crew Size	Flight Duration	Man-Hours
Mercury Redstone:			
3	1	:15	:15
4	1	:16	:16
Subtotal	2	:31	:31
Mercury Atlas:			
6	1	4:55	4:55
7	1	4:56	4:56
8	1	9:13	9:13
9	1	34:20	34:20
Subtotal	4	53:24	53:24
Gemini Titan:			
3	2	4:53	9:46
4	2	97:56	195:52
5	2	190:55	381:50
7	2	330:35	661:10
6	2	25:51	51:42
8	2	10:41	21:22
9	2	72:21	144:42
10	2	70:47	141:34
11	2	71:17	142:34
12	2	94:35	189:10
Subtotal	20	969:51	1,939:42
Apollo Saturn 1:			
7	3	260:09	780:27
Apollo Saturn 5:			
8	3	147:01	441:03
9	3	241:01	723:03
10	3	192:03	576:09
11	3	195:19	585:57
12	3	244:36	733:48
13	3	142:55	428:45
14	3	216:02	648:06
15	3	295:12	885:36
16	3	265:51	797:33
17	3	301:52	905:36
Subtotal	30	2,241:52	6,725:36
Skylab:			
2	3	672:50	2,018:30
(undocked)		(19:45)	(59:15)
(docked)		(653:05)	(1,959:15)
3	3	1,427:09	4,281:27
(undocked)		(11:35)	(34:45)
(docked)		(1,415:34)	(4,246:42)
4	3	2,017:16	6,051:48
(undocked)		(11:44)	(35:12)
(docked)		(2,005:32)	(6,016:36)
Subtotal	9	4,117:15	12,351:45
Apollo–Soyuz test project	3	217:28	652:24
Total (U.S.) [1]	71	7,860:30	22,503:49
World total	121	13,156:06	33,243:55

[1] Breakdown for U.S.:

	Persons	Number
4 times	4	16
3 times	3	9
2 times	10	20
1 time	26	26
Total	43	71

SOURCES: NASA press releases.

TABLE 3-9.—COMPARATIVE TIME SPENT ON SPACE MISSIONS

Astronaut	Nationality	Flights	Total hours: minutes
Carr	US	1	2017:16
Gibson	US	1	2017:16
Pogue	US	1	2017:16
Sevastyanov	Soviet	2	1936:19
Klimuk	Soviet	2	1700:15
Bean	US	2	1671:45
Garriott	US	1	1427:09
Lousma	US	1	1427:09
Conrad	US	4	1179:38
Lovell	US	4	715:04
Grechko	Soviet	1	709:20
Gubarev	Soviet	1	709:20
Volkov	Soviet	2	689:03
Kerwin	US	1	672:50
Weitz	US	1	672:50
Dobrovolskiy	Soviet	1	570:22
Patsayev	Soviet	1	570:22
Cernan	US	3	566:16
Scott	US	3	546:54
Young	US	4	533:34
Nikolayev	Soviet	2	519:22
Stafford	US	4	507:40
Borman	US	2	477:36
Popovich	Soviet	2	448:27
Artyukhin	Soviet	1	377:30
McDivitt	US	2	338:57
Gordon	US	2	315:53
Evans	US	1	301:52
Schmitt	US	1	301:52
Schirra	US	3	295:13
Irwin	US	1	295:12
Worden	US	1	295:12
Aldrin	US	2	289:54
Collins	US	2	266:06
Mattingly	US	1	265:51
Duke	US	1	265:51
Kubasov	Soviet	2	261:13
Filipchenko	Soviet	2	261:05
Eisele	US	1	260:09
Cunningham	US	1	260:09
Schweickart	US	1	241:01
Shatalov	Soviet	3	237:59
Cooper	US	2	225:15
Brand	US	1	217:28
Slayton	US	1	217:28
Shepard	US	2	216:17
Mitchell	US	1	216:02
Roosa	US	1	216:02
Yeliseyev	Soviet	3	214:25
Armstrong	US	2	206:00
Rukavishnikov	Soviet	2	190:10
Lebedev	Soviet	1	188:55
Leonov	Soviet	2	168:33
Anders	US	1	147:01
Haise	US	1	142:55
Swigert	US	1	142:55
Bykovskiy	Soviet	1	119:06
Shonin	Soviet	1	118:42
Gorbatko	Soviet	1	118:41
White	US	1	97:56
Beregovoy	Soviet	1	94:51
Volynov	Soviet	1	72:56
Tereshkova	Soviet	1	70:50
Komarov	Soviet	2	50:54
Demin	Soviet	1	48:12
Sarafanov	Soviet	1	48:12
Khrunov	Soviet	1	47:49
Lazarev	Soviet	2	47:36
Makarov	Soviet	2	47:36
Belyayev	Soviet	1	26:02
Titov	Soviet	1	25:18
Yegorov	Soviet	1	24:17
Feoktistov	Soviet	1	24:17
Grissom	US	2	5:09
Carpenter	US	1	4:56
Glenn	US	1	4:55
Gagarin	Soviet	1	1:48
Totals;			
U.S., 43 persons		31	22, 503:49
U.S.S.R., 34 persons		27	10, 739:46
World, 77 persons		58	33, 243:35

SOURCES: TASS bulletins and NASA press releases.

TABLE 3-10.—LIST OF DECEASED ASTRONAUTS AND COSMONAUTS*

Name/Country	Program**	Date	Cause of Death
Adams/US	MOL X-15	Nov. 15, 1967	X-15 crash
Bassett/US	NASA	Feb. 28, 1966	Jet crash
Belyayev/USSR		Jan. 10, 1970	Complications from surgery
Chaffee, US	NASA	Jan. 27, 1967	Apollo 204 fire
Dobrovolskiy, USSR		June 29, 1971	Soyuz II depressurization
Freeman/US	NASA	Oct. 31, 1964	Jet crash
Gagarin USSR		Mar. 27, 1968	Jet crash
Givens/US	NASA	June 6, 1967	Automobile accident
Grissom/US	NASA	Jan. 27, 1967	Apollo 204 fire
Komarov/USSR		Apr. 24, 1967	Soyuz I crash
Lawrence/US	MOL	Dec. 8, 1967	Jet crash
McKay/US	X-15	May , 1975	Complications from 1962 X-15 crash; after leaving program
Patsayev/USSR		June 29, 1971	Soyuz II depressurization
Rogers/US	X-20	Sept. 13, 1967	F-105 explosion; after leaving program
See, US	NASA	Feb. 28, 1966	Jet crash
Taylor/US	MOL	Sept. 1970	Jet crash; after leaving program
Walker/US	X-15	June 8, 1966	Jet Crash
White/US	NASA	Jan. 27, 1967	Apollo 204 fire
Williams/US	NASA	Oct. 15, 1967	Jet crash
Volkov/USSR		June 29, 1971	Soyuz II depressurization

* The list of deceased cosmonauts is believed to be incomplete. It includes all publicly announced deaths, but a highly placed Russian space official indicated privately to his American counterpart in April 1974 that eight Soviet cosmonauts in training have been killed in aircraft or automobile accidents since 1960, before having had any opportunity to fly in space.

**U.S. casualties include not only NASA astronauts but those men who achieved the astronaut rating in three other programs: X-15, X-20 DynaSoar, and Manned Orbiting Laboratory (MOL). Several have died since leaving (or termination of) their respective programs, but are listed for the sake of completeness.

SOURCES: Assorted press releases.

CHAPTER THREE ANNEX

THE APOLLO-SOYUZ TEST PROJECT

By Vikki A. Zegel*

The Soyuz 19 mission was the Soviet portion of the Apollo-Soyuz Test Project, (ASTP), a joint United States and Soviet space endeavor in 1975. Launched July 15, 1975 from Tyuratam with cosmonauts Col. Aleksey A. Leonov and Valeriy N. Kubasov on board, the Soyuz 19 craft remained in orbit for 6 days. During this time, rendezvous and docking exercises, hardware tests, crew exchanges and joint experiments were carried out with the simultaneously orbiting United States Apollo spacecraft and crew. The Soviet portion of the mission was successfully completed on July 21, 1975, with the two cosmonauts landing safely near Arkalyk, some 2,000 km southeast of Moscow.

The ASTP had been provided for as part of an agreement between the United States and the Soviet Union on cooperation in the exploration and peaceful uses of outer space, signed May 24, 1972.

Preparations for the project involved nearly three years of joint working group exchanges, engineering and technical design developments, cosmonaut training sessions, language education, mission simulations, and a host of historically unprecedented cooperative achievements.

The ASTP proved to be a project of both political and technological significance for both nations. The successful demonstration of the androgynous peripheral docking system (APDS), designed jointly by United States and Soviet engineers for the mission, was the major technological achievement. Politically, the successful completion of the mission was felt to have strengthened the spirit of détente between the two countries, and to have laid the groundwork for their possible future cooperative efforts in space. In addition, the Soviet space program was, for the first time, brought more directly into public view, with unprecedented coverage by the media of launches, landings and mission highlights. This can only be viewed as a political "plus" for the Soviet Union, as public approval of an already popular program was thereby strengthened.

In retrospect, the mission may be viewed as a political step forward for both nations toward the realization of the goals set forth in the May 24, 1972 agreement.

I. Mission Summary [1]

Soyuz 19 was launched at 1220 GMT July 15, 1975 from the Baykonur Cosmodrome near Tyuratam. Approximately seven and one-

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[1] ASTP FACT SHEET, NASA Release No. 74-196, PP. 13-15.

half hours later (1950 GMT) the United States Apollo craft was launched from the Kennedy Space Center at Cape Canaveral, Florida. Launched in a north-easterly direction, the Soyuz 19 was inserted into a 188 by 228 km orbit at an inclination of 51.8°. On the fourth and seventeenth orbits the Soyuz completed two maneuvers to circularize the orbit at 225 km. The Apollo craft, also launched in a north-easterly direction, was inserted into a 150 by 167 km orbit, with the same inclination of 51.8°. About one hour after Apollo orbital insertion, the Apollo Command and Service Module (CSM) began the transposition and docking procedure to extract the docking module from the launch vehicle. (The maneuver was very similar to the Apollo extraction of the lunar module employed during lunar landing missions.) The Apollo spacecraft performed its orbital circularization maneuver at the third apogee to establish a controlled Apollo rendezvous maneuver sequence. After several phasing maneuvers by both spacecraft to adjust altitude differences, a co-elliptical orbit was achieved, thereby establishing a near-constant altitude differential between the two. Rendezvous and docking of the two spacecraft were completed at 1615 GMT on July 17, 1975. The Soyuz and Apollo remained docked for two days, completed several un-docking and redocking maneuvers, and finally separated for the last time at 1530 GMT on July 19, 1975. During the two days the spacecraft were docked, several crew transfers took place, but at no time were there more than three persons in one craft. Several joint experiments, which will be described in subsequent paragraphs, were also carried out during this period. Soyuz 19 landed safely at 1051 GMT July 21, 1975, near Arkalyk, some 2,000 km southeast of Moscow. (The Apollo craft splashed down at 2120 GMT in the Pacific Ocean near Hawaii July 24, 1975. During their final descent, the three Apollo astronauts inhaled a small amount of nitrogen tetroxide, a poisonous gas, which had leaked into the Apollo cabin. It was later determined that the leak occurred because the crewmen had failed to shut off manually the spacecraft's rockets after realizing that the automatic switch had not been activated by Astronaut Brand. That command had not been heard by Brand because of an excessive amount of interference noise in the spacecraft during re-entry. The astronauts were kept under close surveillance in sick bay at Honolulu Hospital for two weeks following the flight, and NASA doctors dismissed them with clear health reports on August 7, 1975.)

A. ASTP CREWS

Four, two-man Soviet cosmonaut crews were named for the ASTP mission. These consisted of two prime and two backup crews, with the second crews prepared to launch after the first if there had been any delays in the United States Apollo launch schedule. As it turned out, the Soviet first prime crewmen, Col. Aleksey A. Leonov (Command Pilot) and civilian Valeriy N. Kubasov (Flight Engineer) became the actual ASTP Soviet crew. (Others named included: second prime crewmen Col. Anatoly V. Filipchenko and Nikolay N. Rukavishnikov; first backup crewmen Maj. Vladimir Dzanibekov and Boris Andreyev; and second backup crewmen Maj. Yuriy Romanenko and Aleksandr Ivanchenkov.)

The United States prime crew members were Brig. Gen. Thomas P. Stafford, Commander; Vance D. Brand, Command Module Pilot; and

Donald K. ("Deke") Slayton, Docking Module Pilot. The United States only named one astronaut backup crew, consisting of Capt. Alan L. Bean, Capt. Ronald E. Evans, and Lt. Col. Jack R. Lousma.

B. ASTP HARDWARE

Soyuz 19 was a modified version of the Soyuz capsule used for all the other Russian manned Soyuz flights since 1967. One major modification was the compatible rendezvous and docking system, jointly designed by United States and Soviet engineers. (This same apparatus was carried on the outward end of the Docking Module, carried by the United States Apollo craft during the mission.) Another major change involved the Soyuz craft pressure and air composition control systems. Soyuz pressure is ordinarily maintained at a normal atmospheric (sea-level) pressure of 760 mm Hg. The United States works at a low pressure of 260 mm Hg. In order to make crew transfers easier, the Soyuz pressure was reduced to 520 mm Hg. The oxygen content of the Soyuz nitrogen-oxygen air mixture was also increased to about 40% to bring it closer to the United States Apollo pure oxygen atmosphere. Several other modifications included changes in flight and attitude controls and radio communications systems, equipment additions, and adjustment of the life support system to enable it to handle more people during crew transfers. These changes required design adjustments of the Soyuz craft, which were tested during the Soyuz 16 (ASTP precursor) flight. The Soviet regular Soyuz launch vehicle was used for the ASTP.

The United States used its Saturn I–B launch vehicle to put the Apollo module into orbit. The Apollo Command and Service Module itself was a modified version of the CSM used during the earlier Apollo lunar landing missions. Modifications included provision for experiments, extra propellant tanks, and the addition of controls and equipment required for proper operation of the Docking Module and the universal docking system. The Docking Module was cylindrical in shape, having a diameter of approximately 1.5 meters and a length of about 3 meters. It served as an airlock for the internal transfer of crewmen between the different atmospheres of the Apollo and Soyuz spacecraft. The Docking Module was equipped with radio and TV communications, antennas, stored gases, heaters, and the displays and controls necessary for transfer operations. The Docking Module was designed to handle two crewmen simultaneously. Hatches having controls on both sides were installed at each end of the module. A universal docking system capable of functioning with similar components on the Soyuz-type spacecraft was located at the Soyuz receiving end of the Module. The Apollo end of the Docking Module used the same type of system that was used in the Apollo lunar landing missions for docking between the Command Module and the Lunar Module.

C. ASTP EXPERIMENTS [2]

The program of scientific experiments conducted during the mission included both unilateral and joint experiments. In the following paragraphs, these are designated as "U" (U.S.S.R. only) or "J" (joint experiments):

[2] Apollo-Soyuz Test-Project 1975 Soviet Press Release, pp. 121–152.

1. Photography of the solar corona and zodiacal light against the background of the night sky (*U*)

A number of shots of the night and dusk sky with the sun at different angles behind the Earth's horizon (conditions of solar eclipse by the Earth) were taken in an attempt to find coronal rays at large angular distances from the Sun.

2. Investigation of refraction and transparency of the upper layers of the atmosphere (*U*)

Atmospheric refraction was determined from solar disc image flattening in photographs taken of the Sun as it rose and set behind the Earth's horizon. Photographs were also taken of setting stars.

3. Photography of daytime and dusk horizon (*U*)

Visual observation and photography of light effects in the vicinity of the spacecraft were carried out in an attempt to determine the characteristics of light-scattering by atmospheric air, investigate various layers of aerosol, investigate certain types of clouds, and analyze the dependence of altitude aerosol distribution on geographical and meteorological factors.

4. Microorganisms Growth (*U*)

To study the effects of weightlessness and space radiation and the Earth's magnetic field on the growth of microorganisms, a culture of protea vulgaris was placed in a thermostatically-controlled capsule known as a "Biokat" and observed.

5. Fish embryonic development (*U*)

To study the growth and development of water animals under space conditions, regular aquarium fish as well as their fertilized roe were inserted into "Biokat" aquaria for observation.

6. Genetic Experiments (*U*)

In order to study the effects of weightlessness on cell division and genetic mutation in biological organisms, various types of seeds were placed in one of the "Biokats" and observed.

7. Artificial Solar Eclipse (*J*)

A series of onboard photographs taken from the Soyuz of the solar corona "atmosphere" around the Apollo while it eclipsed the Sun provided a record of the first solar eclipse produced by man. This experiment was of particular interest to scientists because of the relative infrequency of naturally occurring solar eclipses.

8. Ultraviolet Absorption (J)

To measure the concentrations of atomic oxygen and nitrogen in space at the altitude of the mission, different types of mass-spectrometers were used on board. The method of resonance absorption within the ultraviolet spectrum was employed to determine the densities of these components of the outer atmosphere.

9. Zone-forming Fungi (J)

In order to study the effects of space flight factors on biological rhythms, two cultures of the Pushchino strain of Actinomyces levories (fungi) were observed. Each had been cultivated within different time zones (United States and Soviet Union) approximately 9 hours apart, 7 days prior to launch.

10. Microbial Exchange Test (J)

Microflora microbial samples were taken from cosmonauts and astronauts before, during and after the flight to determine the character and conditions of microbial exchange among men confined in a sealed compartment.

11. Furnace System Experiments (J)

This series of joint "multipurpose furnace experiments" was conducted in order to determine the effects of weightlessness on some metallurgical and chemicrystallization processes in metals and semiconductors.

II. Historical Background

Since 1957, the two themes of United States-Soviet space relations have been competition and cooperation. With the passage of time, the competition in terms of propaganda has diminished and the tentative efforts on both sides to propose limited sharing of information and some joint experimentation have gradually strengthened.

A. ASTP AGREEMENT

The Apollo-Soyuz Test Project was provided for as part of an agreement on cooperation in the exploration and peaceful uses of outer space, signed May 24, 1972 in Moscow by then President Nixon and Chairman Kosygin. Article Three of that document states the following: [3]

> The parties have agreed to carry out projects for developing compatible rendezvous and docking systems of the United States and Soviet manned spacecraft and stations in order to enhance the safety of manned flight in space and to provide the opportunity for conducting joint scientific experiments in the future. It is planned that the first experimental flight to test these systems be conducted during 1975, envisaging the docking of a U.S. Apollo-type spacecraft and a Soviet Soyuz-type spacecraft with visits of astronauts in each other's spacecrafts. The implementation of these projects will be carried out on the basis of principles and procedures which will be developed in accordance with the summary of results of the meeting between representatives of the U.S. National Aeronautics and Space Administration and the U.S.S.R. Academy of Sciences on the question of developing compatible systems for rendezvous and docking and manned spacecraft and space stations of the U.S.A. and the U.S.S.R., dated April 6, 1972.

B. U.S.-SOVIET COOPERATION

The Apollo-Soyuz Test Project was the first joint *manned* space mission involving the United States and the Soviet Union, but there have been several other cooperative space-related endeavors between the two nations.

Efforts to develop U.S.-Soviet cooperation in space research may be traced back to the early space projects planning in 1955 for the International Geophysical Year (IGY). Further efforts were made at various times, but none of these was generally productive until 1962. The United States at that time made specific proposals which resulted in talks between the late Soviet Academician Anatoliy A. Blagonravov, and the late Dr. Hugh L. Dryden, who was then Deputy Administrator of the National Aeronautics and Space Administration. As a result, a three-part, bi-lateral space agreement was drawn up in

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[3] Text of US/USSR Space Agreement. NASA NEWS Special Release, May 24, 1972.

June 1962 which provided for: 1.) coordinated U.S. and Soviet launchings of experimental meteorological satellites, with data to be exchanged over a Washington-Moscow "cold-line"; 2.) launchings by both countries of satellites equipped with absolute magnetometers, with subsequent exchange of data to arrive at a map of the Earth's magnetic field in space; and 3.) joint communications experiments using Echo 2, the U.S. passive satellite.

Unfortunately, the substance and timeliness of the weather data were disappointing, as were the results of the magnetic field maps agreement. Likewise, the passive communications efforts with Echo 2 came to little.

The Dryden-Blagonravov talks led to a second agreement in November 1965, for the preparation and publication of a joint U.S.-Soviet review of space biology and medicine. (This study has been completed, but, to date, has been distributed only in part.)

A new phase of the U.S.-Soviet space relationship began in 1969, when NASA Administrator Dr. Thomas O. Paine wrote to Soviet Academy President Keldysh and Academician Blagonravov, inviting new initiatives in space cooperation, in general scientific fields, and in rendezvous and docking of manned spacecraft. It was agreed to pursue these suggestions.

The ASTP talks actually began in October 1970 when rendezvous and docking discussions were initiated in Moscow. These related to the possibility of each nation designing a manned spacecraft with a docking mechanism compatible with that of the other nation. More general discussions on this topic were resumed in January 1971. In agreements resulting from these talks, procedures were outlined whereby the two countries could arrive at compatible systems, through a combination of coordination and independent action. Joint working groups were established which developed the technical understandings required for design of these systems. In April 1972, the necessary management and operational understandings were established to warrant a government-level commitment to a joint test docking mission, the ASTP, in 1975. The possibility of using the compatible docking systems in future generations of spacecraft was also mentioned.

In addition to the aforementioned talks which led to the decision on the ASTP, broader discussions on cooperation in space science and applications took place in January 1971 in Moscow. As a result of these talks, an agreement was reached which provided for: (1) exchange of lunar samples obtained in Apollo and Luna programs; (2) exchange of weather satellite data between the United States National Oceanic and Atmospheric Administration (NOAA) and the Soviet Hydrometerological Service; (3) coordination of networks of meteorological rocket sounding along selected meridional lines; (4) development of a coordinated program to utilize space and Earth resources survey techniques to investigate the natural environment in areas of common interest; (5) joint consideration of the most important scientific objectives for exchange of results from investigation of near-Earth space, the Moon, and the planets; and (6) exchange of detailed medical information of man's reaction to the space environment.

C. U.S.-SOVIET PRELIMINARY TALKS [4]

The following chronology traces the steps leading to the Apollo-Soyuz Test Project:

October 28, 1970:
—Agreed to design compatible rendezvous and docking systems for future manned spacecraft.
—Agreed to a procedure by which the two sides could, through a combination of independent action and coordination, arrive at compatible systems.
—Established three joint working groups.

June 21–25, 1971:
—Agreed to study the technical and economic implications of early test missions using existing vehicles.
—Agreed on coordinate systems to be used for rendezvous purposes.
—Agreed on single documentation of requirements for atmospheres, hatches, and crew transfer techniques.
—Agreed on air lock volume.
—Agreed on placement of structural elements and equipment.
—Agreed on optical and radio beacon characteristics.
—Agreed on requirements for communications between spacecraft and between spacecraft and ground stations systems.
—Agreed on characteristics of control stations.
—Agreed on docking system basic functions and design features, and spacecraft mass properties.

November 29–December 6, 1971:
—Agreed on technical feasibility of a test mission using existing spacecraft.
—Agreed on objectives and preliminary documentation requirements for a possible test mission.
—Substantially completed documentation on life support systems, coordinate systems and constraints on spacecraft configuration.
—Identified guidance and control systems and on-board equipment of U.S. and U.S.S.R. spacecraft which would need to be compatible.
—Substantially completed documentation on lights, docking targets and contact conditions, control systems and radio tracking.
—Agreed to basic values for a compatible docking system including tunnel diameter for astronaut passage.
—Reached preliminary agreement on the basis for design of an androgynous docking device.

April 4–6, 1972:
—Confirmed the desirability of conducting a test mission using existing spacecraft in 1975.
—Accepted, as the basis for joint specification of management and operational guidelines for joint mission, documents on "Proposed Organization Plan for the Apollo/Soyuz Test Mission," "Apollo/Soyuz Test Mission Considerations," "A Project Technical Proposal Document," and "A Project Schedule Document."
—Agreed on specific principles illustrative of those which will apply in the preparatory and operational periods:
  —Frequent direct contact between project personnel on both sides.
  —Detailed commitments to schedules.
  —A comprehensive test, qualification, training and simulation program.
  —Involvement of mission flight and ground crew personnel in joint working groups two years before the mission.
  —Engineering agreement in July 1972.
  —Control of own spacecraft and spacecraft situations, with certain preplanned guidelines to be worked out.
  —Consultation on control actions affecting joint elements of the mission.
  —Pre-planned in-flight information exchanges, including TV.
  —Reciprocal language familiarity among flight crews.
  —A public information program respecting the policies and practices of both sides.

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[4] U.S. Senate Committee on Aeronauticol and Space Sciences, Hearisg: "Space Agreements With the Soviet Union", Washington: U.S. Government Printing Office, June 23, 1972, p. 61–62.

1. Key Personnel

Soviet:

M. V. Keldysh, President, Academy of Sciences of the USSR
V. A. Kotelnikov, Vice-President, Academy of Sciences
B. N. Petrov, Academician and President of Intercosmos
K. D. Bushuyev, Apollo-Soyuz Test Project Director, Chairman of Joint Working Group One
V. P. Legostayev, Chairman, Working Group Two
V. S. Syromyatnikov, Chairman, Working Group Three
I. P. Rumyantsev, Intercosmos

United States:

G. M. Low, Deputy Administrator, NASA
D. D. Myers, Associate Administrator for Manned Space Flight, NASA
A. W. Frutkin, Assistant Administrator for International Affairs, NASA
R. R. Gilruth, Former Director, NASA Manned Spacecraft Center, Houston, Texas
C. C. Kraft, Director, NASA Manned Spacecraft Center
G. S. Lunney, Apollo-Soyuz Test Project Director, Chairman, Working Group One
D. C. Cheatham, Chairman, Working Group Two
D. C. Wade, Chairman, Working Group Three

III. Joint Preparations

Soon after the May 1972 agreement was signed, numerous joint working group meetings and astronaut-cosmonaut and flight crew training sessions were planned to take place in both the United States and the Soviet Union. The first planning session after the signing of the agreement, took place in July 1972 at the Manned Spaceflight Center in Houston. Members of this group were basically the same participants of the June 1971 meeting, who first discussed the feasibility of compatible docking systems for the joint project. Subsequent to the July 1972 meeting, working groups met regularly (some monthly) in both countries. In addition, the ASTP hardware underwent extensive verification testing at the NASA Johnson Space Center in Houston as well as at the U.S.S.R. Cosmodrome.

A. Astronaut and Cosmonaut Training

Initial familiarization of Soviet cosmonaut and flight support crews with Apollo systems took place during a two-week session in Houston in July 1973. The United States crews were given an opportunity to work with the Soyuz craft during a subsequent joint session in Moscow in November 1973. The Soviet flight crews worked at the Johnson Space Center in late April and early May 1974, and were followed by a return visit of the United States crews to Moscow in June and July 1974. The Soviet cosmonauts visited the United States in September 1974 for a third joint crew training session, and they completed their fourth and final training session in the United States in February 1975. This exercise at the Johnson Space Center in Houston was very extensive, including training in the command and docking module simulators and mockups, joint language training, briefings on experiments, contingencies and mission rules, and other related activities. United States crew members visited the Soviet Union in late April and early May, 1975, to complete the joint crew training. The U.S. astronauts became the first Americans to view Soviet launch facilities when they visited Tyuratam on April 28, 1975 for a tour of ASTP-related hardware.

B. SIMULATIONS

In addition to the planning sessions, joint working group meetings, and crew training sessions, three simulation sessions between flight controllers and ASTP crewmen in Houston and Moscow were conducted in preparation for the flight. These were May 13, May 15, and May 19, 1975 respectively. They involved communications links between the two control centers, including voice, teletype, datafax, and television, and fully manned control center facilities. Final simulations were conducted June 30–July 1, 1975 by the Houston and Moscow control centers and crewmen.

Beyond mission simulations tests, the Soviet Union ran a complete mission test of the Soyuz hardware modifications and ASTP docking procedures on the Soyuz 16 flight in December 1974. This ASTP manned precursor flight is discussed in more detail in an earlier section of this report.

C. ASTP DOCKING SYSTEM DEVELOPMENT

The Russians refer to the Apollo-Soyuz Test Project Docking System as the "androgynous peripheral docking system" or APDS. It was jointly designed by United States and Soviet engineers to provide a universal docking mechanism that could theoretically be used between any two spacecraft for future unilateral or international space endeavors. Following is the description of the APDS development, which appears in the Soviet pre-launch ASTP Press Kit: [5]

1. APDS Development

During the first meeting of the Soviet and American specialists in October 1970 both sides provided data to develop a principle structure scheme of docking system.

It was necessary to develop an active/passive system capable of docking with any spacecraft of the given type (androgynous type). The U.S. and U.S.S.R. specialists provided different schematics of docking systems. In addition, an androgynous principle was defined (the so-called principle of reverse symmetry).

The second meeting was held in June, 1971, in Houston, U.S.A. For this meeting the U.S.S.R. side had prepared a new draft of "Technical Requirements for Docking Systems". The draft was used as a basis to determine technical requirements for development of the systems.

By the meeting in the fall 1971 the both sides had prepared their own drafts for a principle structure scheme. As a result of the discussion joint features of the scheme, which were to meet the compatibility requirements were worked out. It was also agreed upon that each side would develop its own system, and these systems could differ from each other. Most of the Soviet proposals on the principle scheme had been adopted.

It was decided to provide to the U.S.S.R. and U.S. docking systems compatibility by using a common principle structure scheme and standardizing main dimensions of interacting elements when fulfilling

[5] Apollo-Soyuz Test Project—Information for the Press 1975 (Soviet prepared portion of a two-volume U.S.-Soviet publicatios).

the technical requirements for the structure. In addition, loads, temperatures and some other similar parameters were regulated.

In the course of development and fabrication [the] docking system of each country was thoroughly worked at and tested separately and jointly by each side.

First the U.S.S.R. and U.S. docking systems (D.S.) scale mock-ups were tested jointly, then their full-scale mock-ups. Development tests were performed as well as testing of docking systems, practically identical to those to be used during the mission. And at last the preflight mate check of U.S.S.R. and U.S. flight D.S. was performed. Moreover, the U.S.S.R. Docking System was installed on Soyuz 16 and thoroughly tested during the space flight. In this flight, a special ring simulated the Apollo docking ring. Main docking and undocking operations, including the functioning of latches which provide rigid connection of spacecraft were checked.

D. SPACECRAFT ATMOSPHERE AND PRESSURE DIFFERENCES

As discussed under *ASTP Hardware* above, the United States and Soviet Union normally maintain different spacecraft pressures and atmospheric compositions during spaceflights. Crew transfers between the 760 mm Hg/oxygen-nitrogen Soyuz atmosphere and the 260 mm Hg/pure oxygen Apollo environment would have been extremely difficult. Transfers from Soyuz to Apollo would have necessitated that the crews remain for long periods in the airlock to breathe pure oxygen to force nitrogen from their blood. The problem would have been analogous to that of deepsea divers who surface too quickly and develop "the bends." The problem was avoided by changing the Soyuz spacecraft pressure and air composition to 520 mm Hg/40% oxygen for the transfers. This system had been tested on the Soyuz 16 flight (ASTP manned precursor) in December 1974. It proved to be a successful development on that flight, as well as during the ASTP.

E. COMMUNICATIONS

Two kinds of potential communications problems became evident during the course of the ASTP mission preparations. One involved the spacecraft-to-ground communications, the other involved the astronaut-to-cosmonaut verbal communications across a language barrier. The first of these, (caused by a combination of low orbital altitude and limited number of available ground networks), was alleviated by using the United States Applications Technology Satellite (ATS–6) as a communications link during the flight. The second problem was solved by requiring the United States astronauts to speak Russian to the cosmonauts and the Soviet cosmonauts to speak English to the astronauts during the flight. Both solutions proved to be successful ones during the ASTP mission.

IV. Political Issues

Beyond its merits as a scientific and technical project, the ASTP was a highly political and somewhat controversial mission, acclaimed by some as a major contribution to U.S.-USSR détente, while as-

sailed by others as an expensive waste of time. Politics affected both sides, both jointly and separately, at various stages of the project development. In question were such issues as the value of the mission in relation to détente, the Soviet safety record and its effect on United States confidence, and the feasibility of future U.S.-U.S.S.R. cooperative space endeavors.

A. CONTRIBUTIONS TO DÉTENTE

The Apollo-Soyuz Test Project's political achievement in strengthening the atmosphere of détente between the United States and the Soviet Union may be judged by historians as the most significant aspect of the mission. Certainly the demonstration of meaningful cooperation between these two historically competitive powers is a positive step in this direction. Both sides demonstrated that they have considerably changed their attitudes since the early days of the so-called "space race." The competition, of course, will continue, but it is hoped that the attitudes which were formed during the preparation and implementation of the mission will provide the basis for future cooperative efforts between the United States and the Soviet Union.

B. U.S. DOUBTS—SENATOR PROXMIRE AND THE CIA

In light of several Soviet Soyuz mission failures, doubts about Soyuz hardware safety and reliability were raised by some United States critics prior to the mission. In particular, the Soviet "April 5th Anomaly" (discussed in Chapter Three of this report) prompted United States Senator William Proxmire to call for a briefing by Central Intelligence Agency officials on Soviet space program capabilities. A closed hearing before the HUD and Independent Agencies Subcommittee of the U.S. Senate Appropriations Committee was held June 4, 1975. A summarization of the classified testimony of Carl Duckett, CIA deputy director for science and technology, reported that "I do not think they (the U.S.S.R.) are in good shape to handle two missions at once from the command point of view." [6]

Based upon this testimony, Senator Proxmire released a statement July 2, 1975 urging the U.S. National Aeronautics and Space Administration to postpone the July 15 Apollo-Soyuz Test Project mission "until the Soviet Union brings back to Earth the Russian (Soyuz 18/Salyut 4) cosmonauts already in space." [7]

The U.S. National Aeronautics and Space Administration responded to this statement July 2, 1975, concluding that ". . . the Soyuz 18/Salyut 4 mission does not constitute a hazard to ASTP." [8]

NASA also noted that their calculations indicated a tracking overlap of the two missions would occur in only two instances, one lasting about 30 seconds, the other about 90 seconds.

The ASTP was not postponed, and the joint mission went smoothly and according to plan.

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[6] Summary Report of CIA testimony, Rtmarks of Senator Proxmire, Congressional Record, v. 121, July 14, 1975. "CIA Report on Appolo-Soyul Mission."
[7] Press Release from the Office of U.S. Senator William Proxmire. July 2. 1975.
[8] NASA Statement to Aerospace Daily, volume 74, number 3, July 3, 1975, page 18.

C. POST-ASTP PLANS FOR FUTURE U.S.-U.S.S.R. COOPERATION IN SPACE

It has been reported that both the United States and the Soviet Union are committed to continuing their cooperation in space beyond the ASTP. Indeed, it is felt that much of the project's justification would be lost if nothing further were planned.

At least two post-ASTP cooperative efforts have been agreed to by the two countries. The Soviet Union invited the United States to propose and furnish biology experiments which were carried aboard Kosmos 782, a Soviet biology satellite in November-December 1975. (For a more complete discussion of this flight, see Chapters Three and Four of this report.) The agreement for this experiment was negotiated at the fifth meeting of the joint U.S.-U.S.S.R. working group on space biology and medicine, held from October 26 to November 4, 1974 at Tashkent. In August 1975, the Soviet Union asked the United States National Aeronautics and Space Administration to provide experiments for a second biology satellite in 1977, similar to the 1975 mission.

The United States experiments carried on the 1975 mission were:

Plant tumor growth experiment to study the effects of prolonged weightlessness on plant systems and to quantitatively and qualitatively measure cellular responses to G forces. Carrot slices were used as test specimens.

Carrot cell culture experiment to evaluate the effect of zero-G on plant systems and to determine the effects on normal embryonic tissue development. Carrot cell cultures were used in this experiment also.

Heavy particle radiation experiment to measure the physical parameters of high charge and energy particles on board the spacecraft. Stacks of detectors were placed in each of two biological experiment packages and at four other locations in the spacecraft.

Killifish experiment to evaluate the effects of zero-G on vestibular systems. A graded series of killifish embryos representing key development stages were evaluated. Post-flight analysis will center on normality of vestibular functions and microscopic and physiological changes. Similar experiments with killifish were conducted during the U.S. Skylab flight and the U.S. portion of the ASTP flight.

Embryonic development of fruit flies to evaluate cosmic effects on the aging process of drosophila. This experiment was jointly prepared by scientists of the Moscow Institute of Medical and Biological Problems and the United States National Aeronautics and Space Administration Ames Research Center.

In addition, the Soviet scientists invited the United States experimenters to participate in some seven other tests from the standpoint of post-flight specimen analysis. As a reciprocal gesture, the United States invited Soviet scientists to take part in its experiments.

V. Summary

In summary, it may be said that the successful completion of the Apollo-Soyuz Test Project mission was a step toward the realization of the goals set forth in the May 24, 1972 agreement between the United States and the Soviet Union on cooperation in the exploration and peaceful uses of outer space. The technological cooperation between

engineers and scientists and crew members afforded an opportunity for *individuals* really to work together on a personal level. The preparations for the joint mission were perhaps as important as the flight itself from the standpoint of developing cooperative attitudes. History will be the ultimate judge of its success or failure, but it would appear that the Apollo-Soyuz Test Project has made a significant contribution to the strengthening of détente, and laid the foundation for possible future joint efforts between the United States and the Soviet Union.

CHAPTER FOUR

THE SOVIET SPACE LIFE SCIENCES

By Christopher H. Dodge*

I. Introduction

The Soviet Union was the first country to launch a live organism into an orbit around the Earth. This historical event, the November 3, 1957 flight of Sputnik 2 containing the dog, Layka, ushered in a new era of biomedical research related to manned spaceflight. For one week, the dog orbited around the Earth in a state of weightlessness and was exposed to the then relatively unknown hazards of various ionizing space radiations. After one week, an automatic device poisoned the dog and the experiment was terminated. This was the first indication that a higher vertebrate, fairly similar to man physiologically, could not only withstand the rigors of the rocket launch, but could also tolerate for at least one week a variety of spaceflight factors.

Other biological experiments were to follow (see Chapter Three, Table 3–5, p. 233) finally culminating in the historic flight of Vostok 1 on April 12, 1961 which contained the first human ever to orbit the Earth, Yuriy Alekseyevich Gagarin. As summarized in Chapter Three, Table 3–5, p. 233 of this report, there has followed a rapid sequence of progressively larger, longer duration, and more complicated manned spaceflights (Vostok 2–6; Voskhod 1 and 2; Soyuz 1, and 3–19; and Salyut 1–4) and biological satellites of the Kosmos series. All of these events have been supported by a very large and comprehensive research effort in the space life sciences.

A. INFORMATION RESOURCES

Before proceeding to review the Soviet space life sciences effort, it seems desirable to examine the many sources of information necessary to conduct such a review. In the early phases of the Soviet spaceflight program (roughly 1960–1967), it was difficult to obtain timely and detailed information about the program from the open literature, including scientific journals, monographs, and popular media such as newspapers. First, few people in the United States had a command of the Russian language. Second, it was quite difficult to obtain source material. Therefore, a concerted effort was made in this country to overcome this information gap. Private foundations, academic institutions, and the Federal Government, including military and intelligence concerns, pooled and organized personnel with the proper linguistic and scientific background in order to screen systematically the Russian and East European scientific and technical literature. Some

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early efforts toward this end were quite successful. One such organization, the Aerospace Technology Division of The Library of Congress, provided the Federal Government and other interested concerns with timely compilations of bibliographic materials, abstracts of the Soviet and East European literature, and comprehensive reports synthesized from these materials. As new and more automated methods of processing foreign literature came into vogue, manual operations were phased out. Thus, the Aerospace Technology Division was terminated in 1969.

Since that time, a number of Federal Government and private concerns continue to provide translated and abstracted materials relating to the Soviet spaceflight effort. For example, the Federal Research Division of The Library of Congress provides abstracted materials in the Soviet space sciences for the National Aeronautics and Space Administration (NASA).* Other major organizations which provide published translations and abstracts of the Soviet and East European literature include NASA, the Joint Publications Research Service (JPRS), and a variety of non-Government translation agencies. Most translated and abstracted materials may be obtained from the National Technical Information Service (Springfield, Virginia 22151). The various Federal sources of information related to the Soviet spaceflight effort in general and to the Soviet space life sciences effort in particular are provided in Figure 4–1. A non-government source of information on these subjects (Biotechnology Inc., Falls Church, Virginia) is also depicted in Figure 4–2.

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*The extremely valuable assistance of Mr. Joseph Rowe of the Federal Research Division, The Library of Congress in providing most of the source materials for this Chapter is gratefully acknowledged.

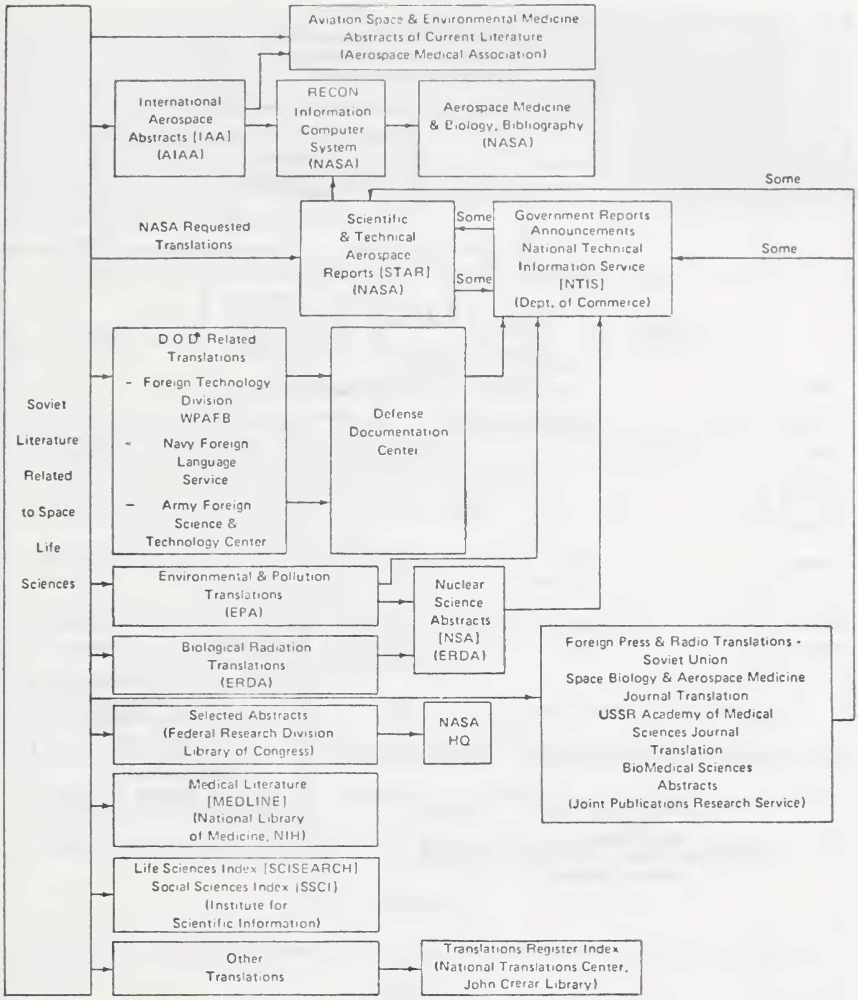

FIGURE 4–1.—Soviet literature agencies and interrelationships.

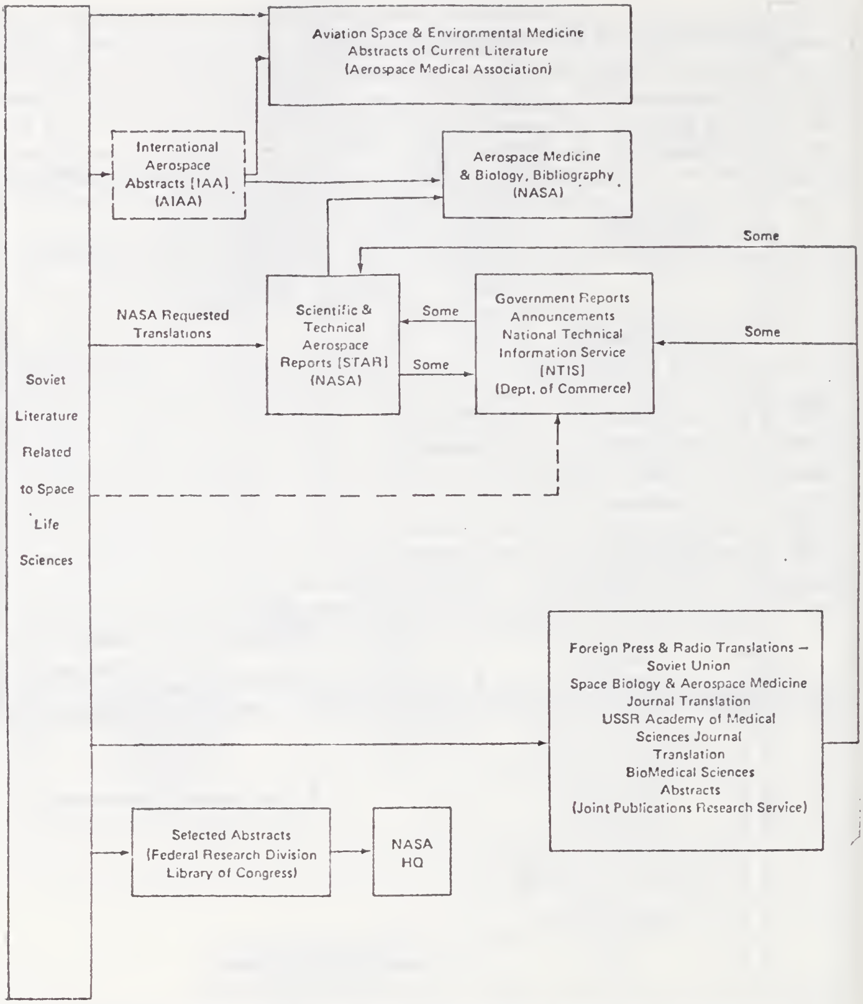

FIGURE 4-2.—Soviet literature for life sciences digest.

Since early 1967, there has been a dramatic increase in published information related to the Soviet manned space effort, particularly in the space life sciences. The trend began with the publication in 1967 of the first Soviet bimonthly journal devoted exclusively to the aerospace life sciences, *Space Biology and Medicine.* Since January, 1974, this journal has carried the title, *Space Biology and Aerospace Medicine.* The counterpart American journal is, *Aviation, Space, and Environmental Medicine.*

The trend toward a more open exchange of information in the space life sciences has been enhanced by détente and the many individual contacts established by American and Soviet specialists at international conferences in the field. Such continuing series of conferences in-

clude the "Man-in-Space", "International Astronautical Federation" (IAF), "Committee on Space Research" (COSPAR), and annual meetings of the United States Aerospace Medical Association (ASMA) to which Soviet space life scientists are invited. Most recently, the trend has been climaxed by the publication of a joint United States and Soviet publication entitled, "Foundations of Space Biology and Medicine". The topical outline for this series is summarized below (Table 4–1).*

TABLE 4–1—FOUNDATIONS OF SPACE BIOLOGY AND MEDICINE

VOLUME I

OUTER SPACE AS A HABITAT

Part I. Physical Properties of Space and Their Biological Significance.
- Chapter 1. Theories of the Origin and Nature of the Universe.
- Chapter 2. Physical Characteristics of Interplanetary Space. E. N. Vernov, Yu. I. Logachev, N. F. Pisarenko.

Part II. Planets and Satellites of the Solar System from the Physical and Ecological (View Points).
- Chapter 3. The Moon and Its Nature. Harold C. Urey.
- Chapter 4. Earth-Type Planets (Mercury, Venus, and Mars) M. Ya. Marov—V. D. Davydov.
- Chapter 5. Giant Planets and Their Satellites, Asteroids, Minor Planets, Meteorites (Including Cosmic Dust), and Comets. Samuel Gulkis, Raymond Newburn.

Part III. Problems of Exobiology.
- Chapter 6. Biological Effects of Extreme Environmental Conditions. A. A. Imshenetsky.
- Chapter 7. Theoretical and Experimental Prerequisites of Exobiology. A. I. Oparin.
- Chapter 8. Search for and Investigation of Extraterrestrial Forms of Life. A. B. Rubin.
- Chapter 9. Planetary Quarantine: Principles, Methods, and Problems. Lawrence B. Hall.

VOLUME II

ECOLOGICAL AND PHYSIOLOGICAL FOUNDATIONS OF SPACE BIOLOGY AND MEDICINE

BOOK ONE

Part I. Influence of the Artificial Gaseous Atmosphere of Spacecraft and Stations on the Organism.
- Chapter 1. Barometric Pressure and Gas Composition. V. B. Malkin.
- Chapter 2. Toxicology of the Air in Closed Spaces. Ralph C. Wands.
- Chapter 3. Thermal Exchange and Temperature Stress. Paul Webb.

Part II. Effect of Dynamic Flight Factors on the Organism.
- Chapter 4. Principles of Gravitational Biology. Arthur H. Smith.
- Chapter 5. Effect of Prolonged Linear and Radial Accelerations on the Organism. P. V. Vasil 'yov, A. R. Kotovskaya.
- Chapter 6. Impact Accelerations. James W. Brinkley and Henning E. von Gierke.
- Chapter 7. Angular Velocities, Angular Acceleration, and Coriolis Accelerations. Ashton Graybiel.
- Chapter 8. Weightlessness. Siegfried J. Gerathewohl and I. D. Pestov.
- Chapter 9. Vibration and Noise. Charles W. Nixon, John Guighard, Henning E. von Gierke.

*At the time of writing, Volume II of the series has been published. The remaining volumes are in the final stages of preparation.

BOOK TWO

VOLUME III

SPACE MEDICINE AND BIOTECHNOLOGY

Source: Federal Research Division, Library of Congress.

Monographic sources of information concerning the Soviet Space life sciences are contained in a series entitled, "Problems of Space Biology." Topics considered since 1967 are listed below:

Problems of Space Biology. Vol. 7. Human Operator Activity; Problems of Habitability, and Biotechnology (Collection of Articles). V. N. Chernigovskiy (Ed.). Moscow, "Nauka" Press, 1967, 552 p.

Ibid. Vol. 8. Adaptation to Hypoxia and Resistance To It. V. N. Chernigovskiy (Ed.). Moscow, "Nauka" Press, 1968, 272 p.

Ibid. Vol 9. Outline of Space Radiobiology. P. P. Saksonov et al. Moscow, "Nauka" Press, 1968, 350 p. (NASA TT-F-604)*

Ibid. Vol. 10. Neural Mechanisms of Vestibular Reactions. A. N. Razumeyev et al. Moscow, "Nauka" Press, 1969, 342 p. (NASA TT-F-605)

Ibid. Vo. 11. The toxicology of Products of Vital Activity and Their Importance in the Formation of Artificial Atmospheres in Hermetically Sealed Chambers. V. V. Kustov et al. Moscow, "Nauka" Press, 1969, 129 p. (NASA TT-F-634)

Ibid. Vol. 12. The Gravitational Receptor. V. N. Chernigovskiy (Ed.). Moscow, "Nauka" Press, 1971, 523 p. (NASA TT-F-720)

Ibid Vol. 13. Prolonged Limitation of Mobility and Its Influence on the Human Organism. A. M. Genin et al. (Eds.). Moscow, "Nauka" Press, 1969, 263 p. (NASA TT-F-639)

Ibid. Vol. 14. Radiobiological Aspects of the Reactivity of the Organism During Spaceflights. P. P. Saksonov et al (Eds.). Moscow, "Nauka" Press, 1971, 398 p.

Ibid. Vol. 15. Functional Morphology During Extremal Actions. Ye. F. Kotovskiy et al. Moscow, "Nauka" Press, 1971, 383 p. (NASA TT-F-738)

Ibid. Vol 16. General Topics. V. N. Chernigovskiy (Ed.). Moscow, "Nauka" Press, 1971, 351 p. (NASA TT-F-719)

Ibid. Vol. 17, Pathophysiological Bases of Aviation and Space Pharmacology. P. V. Vasil'yev et al. Moscow, "Nauka" Press, 1971, 355 p.

Ibid. Vol. 10. Problems of the Resistance of Biological Systems. B. N. Tarusov (Ed.). Moscow, "Nauka" Press, 1971, 288 p.

Ibid. Vol. 20. Mathematical Models of Biological Systems. Yu. M. Svirizhev et al. Moscow, "Nauka" Press, 1972, 159 p. (NASA TT-F-780)

Ibid. Vol. 21. Tissue Oxygen During Extreme Flight Factors. Ye A. Kovalenko et al. Moccow, "Nauka" Press, 1972, 1972, 263 p. (NASA TT-F-762)

Ibid. Vol. 22. Metabolism Under Extreme Conditions of Spaceflight and During Simulation. I. S. Balakhovskiy et al. Moscow, "Nauka" Press, 1973, 211 p.

Ibid. Vol. 24 Problems of Water Supply for Space Crews S. V Chizhov et al Moscow, "Nauka" Press, 1973, 268 p.

Ibid. Vol. 25. Decompression Disorders. P. M. Gramenitskiy. Moscow, "Nauka" Press, 1974, 330 p.

Ibid. Vol. 27. Radiobiology and the Genetics of *Arabidopsis*. V. I. Ivanov. Moscow, "Nauka" Press, Moscow, 1974, 191 p.

In addition to the above, the proceedings of the aforementioned series of conferences are, as a rule, published in Russian and ultimately translated or abstracted.

For those with Russian language background, it is possible to review the Soviet periodical literature directly for articles dealing with the space life sciences. A large number of sources regularly or occasionally publish articles on the subject. An alphabetical listing of these sources is provided below (table 4–2).†

TABLE 4–2.—*Space Life Sciences Source Journals*

	Periodicity (—/(year)
Akusticheckiy Zh. (Acoustics J.)	6/yr.
Antibiotiki (Antibiotics)	12/yr.
Arkhiv Anatomii, Gistologii i Embriologii (Archives of Anatomy, Histology and Embryology)	12/yr.
Arkhiv Patologii (Archives of Pathology)	12/yr.
*Aviatsiya i Kosmonavtika (Aviation and Astronautics)	12/yr.
Biologicheskiye Nauki (Biological Sciences)	12/yr.
Biofizika (Biophysics)	6/yr.
Biokhimiya (Biochemistry)	6/yr.

†Citations in parentheses indicate translation availability.

*Bibliographic citations used in this chapter have been translated into English. Table 4–2 provides Russian transliterations of those citations.

TABLE 4-2.—*Space Life Sciences Source Journals—Continued*

	Periodicity (—/(year)
Byulleten' Eksperimental'noy Biologii i Meditsiny (Bulletin of Experimental Biology and Medicine)	12/yr.
*Doklady Akademii Nauk SSSR (Reports of the Academy of Science, USSR)	36/yr.
Farmakologiya i Toksikologiya (Pharmacology and Toxicology)	6/yr.
*Fiziologicheskiy Zh. SSSR im. I. M. Sechenova (Physiological J. USSR in the name of I. M. Sechenov)	12/yr.
Fiziologichiny Zh. [Ukr.] (Physiological J.)	6/yr.
Gigiyena i Sanitariya (Hygiene and Sanitation)	12/yr.
*Gigiyena Truda i Professional 'nyye Zabolevaniya (Industrial Hygiene and Occupational Diseases)	12/yr.
Izvestiya Akademii Nauk [A.N] Azerbaydzhanskoy SSR. Seriya Biol. (News of the Academy of Sciences [A.S.], Azerbaijan SSR. Biol. Series)	6/yr.
Izvestiya A.N. Kazakhskoy SSR. Seriya Biol. (News of the A.S. of the Kazakh. SSR. Biol Series)	6/yr.
Izvestiya A.N. Moldavskoy SSR. Seriya Biol. (News of the A.S. of the Moldavian SSR. Biol. Series)	6/yr.
*Izvestiya A.N. SSSR (News of the A.S. USSR)	6/yr.
Izvestiya A.N. Tadzhikskoy SSR. Seriya Biol. (News of the A.S. of the Tadzhik SSR. Biol. Series)	6/yr.
Izvestiya A.N. Turkmenskoy SSR. Seriya Biol. (News of the A.S. of the Turkmen SSR. Biol. Series)	
Izvestiya A.N. Estonskoy SSR. Seriya Biol. (News of the A.S. of the Estonian SSR. Biol. Series)	4/yr.
Izvestiya Sibirskogo Otdeleniya AN SSSR. Seriya Biol. (News of the Siberian Branch, A.S. USSR. Biol. Series)	3/yr.
Kazanskiy Meditsinkiy Zh. (Kazan' Medical J.)	6/yr.
*Kardiologiya (Cardiology)	12/yr.
Khimiya i Zhizn' (Chemistry and Life)	12/yr.
Klinicheskaya Meditsina (Clinical Medicine)	12/yr.
*Kosmicheskiye Issledovaniya (Space Research)	6/yr.
*Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina (Space Biology and Aerospace Medicine	6/yr.
*Kryl'ya Rodiny (Wings of the Homeland)	12/yr.
Laboratornoye Delo (Laboratory Practice)	12/yr.
Med. Radiologiya (Medical Radiology)	12/yr.
Med. Tekhnika (Medical Equipment)	6/yr.
Mikrobiologiya (Microbiology)	6/yr.
Mikrobiologichniy Zh. [Ukr. with Russ & Eng. Absts'] (Microbiological J.)	6/yr.
Molekulyarnaya Biologiya (Molecular biology)	6/yr.
*Nauka i Zhizn' (Science and Life)	12/yr.
Neyrofiziologiya (Neurophysiology)	6/yr.
Nervnaya Sistema (Nervous System)	1/yr.[sic]
Oftal'mologicheskiy Zh. (Odessa) (Ophthalmological J.)	8/yr.
*Patologicheskaya Fiziology and Eksperimental 'naya Terapiya (Pathological Physiology and Experimental Therapy)	6/yr.
Prikladnaya Biokhimiya i Mikrobiologiya (Applied Biochemistry and Microbiology)	6/yr.
*Priroda (Nature)	12/yr.
*Radiobiologiya (Radiobiology)	6/yr.
Sovetskaya Meditsina (Soviet Medicine)	12/yr.
Sovetskoye Zdravookhraneniye (Soviet Public Health)	12/yr.
Sovetskoye Zdravookhraneniye Kirgzia (Soviet Public Health of Kirgizia)	6/yr.
Sudebno-Meditsinskaya Ekspertiza (Forensic Medicine)	4/yr.
Tekhnika-Molodezhi (Technology for Young People)	12/yr.
Tsitologiya i Genetka (Cytology and Genetics)	6/yr.
Tsitologiya (Cytology)	12/yr.
Uspekhi Sovremennoy Biologii (Progress in Modern Biology)	6/yr.

*Indicates 20 major journals.
Zh = Zhurnal ; J = Journal.

TABLE 4-2.—*Space Life Sciences Source Journals—Continued*	(—/(year) Periodicity
*Uspekhi Fiziologicheskikh Nauk (Progress in the Physiological Sciences)	4/yr.
*Vestnik Akademii Meditsinskikh Nauk SSSR (Herald of the Acad. of Med. Sci's. USSR)	12/yr.
Vestnik Akademii Nauk SSR (Herald of the Acad. of Sci's USSR)	12/yr.
Vestnik Dermatologii i Venerologii (Herald of Dermatology and Venerology)	12/yr.
Vestnik Leningradskogo Universiteta. Seriya Biol. (Herald of Leningrad University. Biol. Series)	24/yr.
*Vestnik Otorinolaringologii (Herald of Otorhinolaryngology)	6/yr.
Vestnik Oftal'mologii (Herald of Ophthalmology)	6/yr.
*Voyenno-Meditsinskiy Zh. (Military Medical J.)	12/yr.
Voprosy Meditsinskoy Khimii (Problems of Medical Chemistry)	6/yr.
Voprosy Neyrokhirurgii (Problems of Neurosurgery)	6/yr.
*Voprosy Filosofii (Problems of Philosophy)	12/yr.
Voprosy Psikhologii (Problems of Psychology)	6/yr.
Voprosy Pitaniya (Problems of Nutrition)	6/yr.
Vrachebnoye Delo (Physician's Practice)	12/yr.
Zdravookhraneniye Belorussii (Public Health of White Russia)	12/yr.
Zdravookhraneniye Kazakhstana (Public Health of Kazakhstan)	12/yr.
Zdravookhraneniye Kirgizii (Public Health of Kirgizia)	6/yr.
Zdravookhraneniye Moldavii (Public Health of Moldavia)	6/yr.
Zdravookhraneniye Rossiyskoy Federatsii (Public Health of Russian Federation)	12/yr.
Zdravookhraneniye Turkmenistana (Public Health of Turkmenistan)	12/yr.
*Zemlya i Vselennaya (Earth and the Universe)	
*Zhurnal Vysshey Nervnoy Deyatel'nosti im. I. P. Pavlova (Journal of Higher Nervous Activity in the name of I. P. Pavlov)	6/yr.
Zhurnal Mikrobiologii, Epidemiologii i Immunologii (Journal of Microbiology, Epidemiology and Immunology)	12/yr.
Zhurnal Nevropatologii i Psikhiatrii im. S. S. Kosakova (Journal of Neuropathology and Psychiatry in the name of S. S. Korsakov)	12/yr.
Zhurnal Obshchey Biologii (Journal of General Biology)	6/yr.
Zhurnal Evolyustionnoy Biokhimii (Journal of Evolutionary Biochemistry)	6/yr.
Zhurnal Eksperimental'noy i Klinicheskoy Meditsiny (Journal of Experimental and Clinical Medicine)	6/yr.

Superficial information of a more current nature is published in Soviet newspapers such as *Pravda* (Truth), *Izvestiya* (News), *Krasnaya Zvezda* (Red Star), *Meditsinskaya Gazeta* (Medical Gazette), and *Nedel'ya* (Weekly). A number of conferences on the subject of the space life sciences which do not involve international participation are periodically held in the Soviet Union. These include "the All-Union Conferences on Space Biology and Medicine" and meetings of the Aviation and Space Medicine Branch of the I. P. Pavlov Physiological Society. The proceedings of these conferences are often summarized in the aforementioned list of journals or are translated by NASA or JPRS.

Biographic information on Soviet personalities involved in the space life sciences and the institutions in which they work are to be found in two recent studies prepared by The Library of Congress

*Indicates 20 major journals.
SOURCE: Federal Research Division, The Library of Congress.

under the support of the Fogarty International Center of the National Institutes of Health.[1, 2]

Many Soviet monographs dealing with the various disciplines of the space life sciences have been published, particularly within the past six years. Many of the major ones have been footnoted in the text of this report. A sizeable number are routinely abstracted and/or occasionally translated by NASA or JPRS.

The Soviet Union and the United States have made efforts to compile and organize the world literature on the space life sciences. The Soviet effort is reflected in a directory of Soviet and Western sources.[3] The United States effort is reflected in a series of publications entitled, *Aerospace Medicine and Biology: Bibliography* (NASA).

B. ORGANIZATION OF THE SOVIET SPACE LIFE SCIENCES EFFORT

From the foregoing review of the Soviet space life sciences literature, it is evident that the Soviet research effort in this field is very large. In purely quantitative terms of personalities and facilities involved, it would appear to exceed substantially the comparable United States effort. In qualitative terms, the Soviet and United States programs are roughly equivalent. The general organization of the Soviet biomedical institutions involved in the space life sciences effort is summarized in Figure 4–3.

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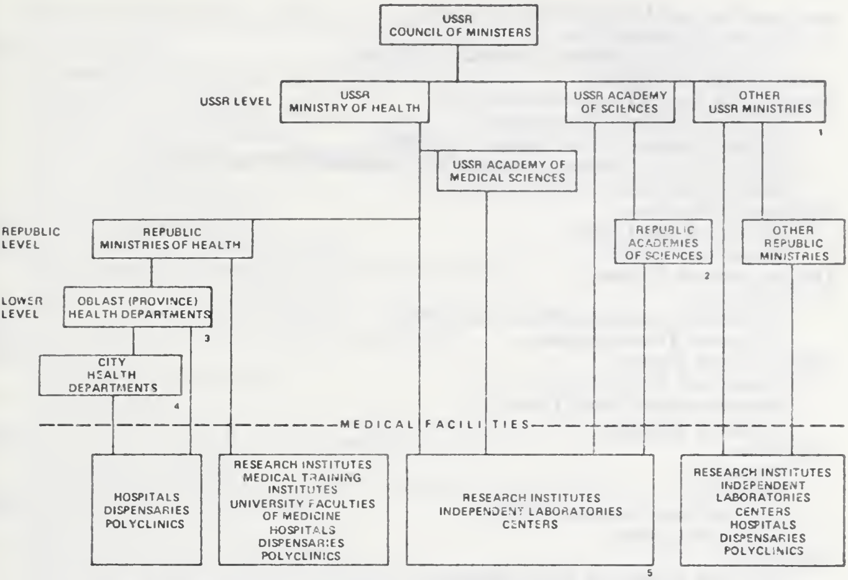
[1] Soviet Biomedical Institutions: A Directory. Washington, D.C., U.S.D.H.E.W. Publication No. (NIH) 74–698. 1974. 553 p.

[2] Soviet Personalities in Biomedicine. Washington, D.C., U.S.D.H.E.W. Publication No. (NIH) 74–699, 1974. 968 p.

[3] Medical and Biological Problems of Spaceflights. Moscow, "Nauka" Press, 1972, 303. p. (Library of Congress. Federal Research Division (FRD) Abstract No. 1029) Federal Research Division abstract citations will henceforth be indicated by, "(FRD #   )."



1 OTHER GOVERNMENT AGENCIES INVOLVED IN PUBLIC HEALTH INCLUDE, AMONG OTHERS, THE USSR MINISTRY OF DEFENSE, USSR MINISTRY OF MEDICAL INDUSTRY, USSR MINISTRY OF RAILWAYS, USSR MINISTRY OF HIGHER AND SECONDARY SPECIALIZED EDUCATION, AND THE USSR ACADEMY OF PEDAGOGICAL SCIENCES UNDER THE USSR MINISTRY OF EDUCATION.

2 REPUBLIC ACADEMIES OF SCIENCES EXIST IN 14 OF THE 15 UNION REPUBLICS, THE RSFSR DOES NOT HAVE A REPUBLIC ACADEMY.

3 ALSO AT THIS LEVEL ARE HEALTH MINISTRIES OF AUTONOMOUS REPUBLICS (ASSR'S) AND HEALTH DEPARTMENTS OF KRAYS (TERRITORIES).

4 ALSO AT THIS LEVEL ARE HEALTH DEPARTMENTS OF RURAL RAYONS (COUNTIES) – SUBDIVISIONS OF OBLASTS, KRAYS, AND ASSR'S. SMALL CITIES WITHIN THE RAYONS ARE UNDER THE JURISDICTION OF THE RAYON HEALTH DEPARTMENTS.

5 THERE ARE SOME HOSPITALS, DISPENSARIES, AND POLYCLINICS SUBORDINATE TO THE IV MAIN ADMINISTRATION OF THE USSR AND REPUBLIC MINISTRIES OF HEALTH. THESE FACILITIES APPEAR TO BE RESERVED FOR HIGH-RANKING MEMBERS OF SOVIET SOCIETY. ALSO, AT LEAST ONE MEDICAL TRAINING INSTITUTE IS SUBORDINATE DIRECTLY TO THE USSR MINISTRY OF HEALTH.

FIGURE 4–3.—Organization of Soviet Biomedical Institutions.

The most prominent facility involved in the Soviet effort is the Institute of Biomedical Problems under the direction of Dr. Oleg Gazenko. This relatively new facility, constructed in the late 1960's, is under the Ministry of Health and is located on the outskirts of Moscow. Many of the articles published in the Soviet journal, *Space Biology and Aerospace Medicine* reflect the research being conducted in or supported by this facility although such articles seldom show instructional affiliation credits. The military Medical Academy imeni Kirov located in Leningrad also plays a prominent role in the Soviet space life sciences program. A great many academic centers and institutes under the USSR Academy of Sciences provide additional support to the program. A listing of some of the more prominent facilities is contained in the still valuable Aerospace Technology Report published in 1965.[4]

Topically, the Soviet space life sciences effort can, for convenience sake, be categorized into physiology and medicine, psychological and behavioral sciences, and human engineering. Under physiology and medicine, the following subjects are being investigated:

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[4] Mandrovskiy, B. Soviet Bioastronautics and Manned Spaceflight. Programs, Organization, and Personalities. Washington, D.C., Library of Congress, Aerospace Technology Division Report No. P–65–14, 1965, 118 p.

Acceleration and Deceleration Effects:
- Impact Accelerations.
- Coriolis Accelerations (vestibular effects).

Acoustic Energy Effects.

Altered and Normal Gas Atmospheres:
- Oxygen (hypoxia, hyperoxia).
- Carbon dioxide (hypercapnia, acapnia).
- Noxious gases (carbon monoxide, pyrolysis by-products etc.).
- Odors (food, body, chemical etc.).

Biological Rhythms:
- Circadian Rhythms.
- Work-Rest Cycles.

Decompression Effects:
- Hypoxia.
- Dysbarism (decompression sickness).
- Explosive Decompression.

Diseases and Injury:
- Cause and Prevention.
- Treatment and Drug Therapy.
- Personal Hygiene.

Nutrition:
- Vitamins.
- Minerals.
- Natural and Synthetic Foods.
- Food Packaging.

Radiation:
- Relative Biological Effectiveness.
- Dose and Dose Rate.
- Somatic and Genetic Effects.
- Protective Measures (drugs, shielding, force fields etc.).

Temperature and Humidity:
- Hyperthermia.
- Hypothermia.

Weightlessness:
- Motor Kinetics.
- Motion Sickness.
- Hypodynamia and Hypokinesia.
- Preventive and Prophylactic Measures.

Work Capacity:
- Fatigue.
- Muscle Tone.

Physical Training and Exercise.

Subjects being investigated in the psychological and behavioral sciences include:

Boredom and Confinement.

Disorientation.

Mental Fatigue.

Motivation and Vigilance.

Neuroses and Psychoses:
- Anxiety.
- Compulsion.
- Depression.
- Phobia.

Personality Dynamics:
- Group Interaction.

Space Crew Problems:
- Requirements.
- Selection and Screening.
- Training.
- Task Analysis.
- Work Schedule and Performance.

Weightlessness Effects:
- Orientation.
- Work-Rest Cycles (sleep et.).

Human engineering subjects include:

Air Conditioning:
- Spacecraft Temperature and Humidity Control.
- Atmosphere Control.
- Oxygen and Diluent Gas Management.
- Carbon Dioxide Removal.
- Photosynthesis of Lower and High Plants.
- Odor Management.
- Toxic Gas Management.

Fire Hazard Management.

General Life Support Management:
- Food Storage, Preservation, and Refrigeration.
- Personal Hygiene Equipment.

Insulation (acoustic and thermal).

Leisure, Exercise, and Recreation Equipment.

Instrumentation:
- Biomedical Monitoring.
- Biotelemetry.
- Communications Equipment (radar, T.V., radio etc.)

Radiation Protection (U.V., I.R., Ionizing etc.):
- Individual Shielding.
- Electrostatic, Magnetic, or Electromagnetic Force Fields.

Safety and Survival Equipment:
- Space Suits.
- Emergency Rescue Equipment.
- Emergency Pressure and Atmosphere Control.
- Repair and Maintenance Equipment.

Sanitation Facilities:
- Waste Management, Disposal, and Storage.

Space Vehicle Controls and Equipment:
- Manual and Automatic Controls.
- Cabin Atmosphere Controls.

Vision:
- Lighting and Color Scheme.
- Instrument and Other Displays.
- Optical Controls (Periscope).

Washing and Hygiene Equipment.

Water Recycling and Purification:
- Respiration, Urine, and Perspiration Management.

Problems of particular concern in the continuing Soviet space life sciences effort include:

Concentrated Ground Laboratory Studies:
- Effect of Hypokinesia (reduced movement):
  - Simulation of Prolonged Weightlessness (improvement in techniques).
- Energy Loss Studies:
  - Gravitational Effects.
  - Space-suit Limitations.
  - Oxygen Deficiency Effects.
- Acceleration Effects:
  - Hyperoxia (high oxygen or air pressures).
  - Metabolic Studies.
  - Pharmaco-dynamics.
  - Biochemistry and Cell Physiology.

Mechanism of Adaptation to Space Factors:
- Role of Neural and Neuro-humoral Mechanisms.
- Regeneration Processes (emphasis on blood cell replacement).
- Central Nervous System Conditioning.
- Inhibition of Cerebellar Functions.
- Vestibular Analyzer Conditioning.
- Eye Effects (vision generally).

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Changes in Permeability of Cellular Structures:
- Ion Transport Mechanisms.
- Kinetics of Erythropoiesis (red blood cell formation).
- Gas Dynamics of Tissues.
- Changes in Homeostatic Constants.
- Alteration of Respiratory Processes.

Functional Conditioning of the Cardiovascular System:
- Role of Brain Centers.
- Vestibular Mechanisms.

Prolonged Artificial Hibernation.

Automated Biochemical Sampling.
- Studies of Changes in Saliva Composition as a Rapid Indicator.

Collection Techniques for Obtaining retailed Physiological Data in Flight:
- Biomedical and Psychological Monitoring.
- Voice Analysis.
- Computer Processing and Transmission of Medical Data.

Protection against spaceflight factors:
- Radiation.
- Weightlessness.
- Altered Gas Atmosphere and Decompression.

Many of the problems outlined above have been directly related to recent space missions. For example, the physiological aspects of altered gas atmospheres and the mechanisms of decompression disorders have received considerable attention since the 1971 Soyuz 11/Salyut 1 mission in which the three cosmonauts were killed during re-entry due to rapid decompression when a valve failed in the landing module. Similarly, the physiological effects of weightlessness or weightless-like states (bed-rest, hypodynamia, confinement etc.) are of continuing concern as Soviet space missions become longer in duration and more complicated programmatically.

In the paragraphs that follow, the more significant trends in the Soviet space life sciences will be reviewed. It is also the intent of this report to provide the reader with the most authoritative sources available in the Soviet literature related to the subjects under review.

II. Cosmonaut Selection and Training

A. The Selection Process

The Soviet process for selecting cosmonaut candidates, like that of the United States, has been refined and modified since the beginning of the manned spaceflight program. In the initial phases of that program, essentially the same principles were used to select cosmonauts as were used to select military aircraft pilots. Thus, the early Vostok series, like the American Mercury series, of spaceflights were exclusively manned by former military pilots who had demonstrated in various rigorous physical, physiological, medical, and psychological tests that they could be expected to withstand the anticipated rigors of spaceflights.[5,6]

Early medical selection procedures for Soviet cosmonauts were extensive because of a general lack of knowledge about the effects of spaceflight factors on humans. They were conducted at multiple sites near the applicants by teams of aviation medical specialists. Although they were conducted without the benefit of extensive equipment, they

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[5] Rukavishnikov, N. N. et al. The Cosmonaut as a Researcher. Moscow, "Inaniye" Press, 1973, 64 p. (NASA TT–f–15, 196).

[6] DeHart, R. Biomedical Aspects of Soviet Manned Spaceflight. Washington, D.C. Defense Intelligence Agency, 1974, 71 p. (ST–CS–13–373–75).

resulted in a 50 percent rejection rate. Causes of rejection were related to disorders of the ears, nose, and throat, visual acuity, internal diseases, neurocirculatory disturbances, and susceptibility to motion sickness.[7]

The medical examination was designed to reveal any pathological or functional disturbances which would disqualify the candidate. After a preliminary examination, a more comprehensive one was then conducted at the Institute of Aviation Medicine near Moscow. After the comprehensive examination, candidates were then exposed to simulated high altitude in pressure chambers to measure the effects of hypoxia and response to decreased atmospheric pressure. Ascent was made to a simulated altitude of about 39,000 ft. Loss of consciousness was apparently not an uncommon event in these early procedures.[8]

Extensive psychological tests, intelligence assessments, and coordination measurements were conducted. Psychological tests were designed to ensure a good match between the cosmonaut and space vehicle control system. Selection of the most appropriate candidate was considered from the viewpoint of recall ability, learning capacity, and other measurements.[9]

Essentially the same selection protocol persists with some modifications, the difference now being that spacecraft are manned by multiple crews, not all of whom have an aviation background. The first such example of this in the Soviet manned spaceflight program was the Voskhod 1 flight in 1964. This vehicle, termed a "spacebus" by Soviet journalists, was manned by a medical doctor (B. B. Yegorov) and a candidate of technical sciences (K. P. Feoktistov), in addition to the pilot cosmonaut (V. M. Komarov). The doctor and scientific worker had no professional flight training.[10] They had passed a special medical selection process, and to the degree necessary, preflight preparation at the Zvezdnyy Gorodok (Star City) cosmonaut training center. The Voskhod 1 flight and postflight analysis showed that all of the crew members encountered no difficulty of any consequence. Since that time, the selection of cosmonauts with no formal flight training has become a common practice in the Soviet manned spaceflight program. At present, the crew of a spacecraft or orbiting laboratory has a fixed nucleus consisting of a pilot-commander and an onboard engineer. In addition, cosmonauts performing various specialized flight or scientific assignments are included in the crew. Preparation is such that an overlapping of function is assured should any one crew member become disabled.[11-12]

The Russians continue to place heavy emphasis on the vestibular system (responsible for balance and orientation) to cosmonaut candidates. This emphasis has its roots in the flight of Vostok 2 in 1961 during which cosmonaut German Titov experienced transient episodes of dizziness and nausea. Since that time, there has been concern that cosmonauts might experience illusions which would render orientation in space difficult or that vestibular-autonomic reactions would cause a

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[7] Link, M.M. and N.M. Gurovskiy. Selection of Astronauts. In: Foundations of Space Biology and Medicine. Vol. III, Part 4., Ch. 15. Washington, D.C. NASA.

[8] Riabchikov, E. Russians in Space. Garden City, N.W., Doubleday and Co., 1971, p. 47–65.

[9] Ibid.

[10] Rukavishnikov, N.N. et al. The Cosmonaut as a Researcher. Op. Cit.

[11] Luxenberg, B. and Zegel, V. Astronaut Information: American and Soviet (4th Revision). Library of Congress. Congressional Research Service. Multilith No. 74–64 SP, April, 1974, 82 p.

[12] Yakovleva, I. Ya. et al. The significance of Coriolis acceleration summation tests for expert selecting. Vestnik Otorinolaringologii (USSR), No. 1, 1974, 25–28 (FRD 1867).

deterioration in well-being to the peril of the flight or flight program. Tests therefore continue to be developed to eliminate candidates with latent vestibular problems. One such test is the Coriolis Acceleration Summation Test in which candidates are rotated in a special chair at angular speed of 180 degrees per minute for 15 minutes. The Russians feel that this test is a valuable supplement to other tests of the vestibular system (otolith reaction; Khilov swing etc.) because it affects all central nervous (cerebral) functions. It is therefore likely to disclose latent flaws that other tests might not detect. Presently, candidates with low tolerance to vestibular tests as exhibited by motion sickness or increased susceptibility to orientation illusions are eliminated. In general, the Soviets appear to place a heavier emphasis on the vestibular testing of candidates than the United States.[13]

Other medical features of importance in the selection process include visual function and acuity, auditory function, the state of the immune system, respiration and gas exchange, water-electrolyte balance, and general metabolism. Because mineral (calcium) metabolism is a problem in space, a wide variety of conditions which could lead to kidney stones and other disorders are used to eliminate candidates. These include a history of renal colic, gall bladder disease, bloody urine, gout, and other diseases.[14]

In the early phases of the Soviet manned spaceflight program, the comprehensive testing of cosmonauts at the Institute of Aviation Medicine who had passed the initial selection process resulted in a rejection of 25–50 percent of the candidates examined. Thus, biomedical selection procedures eliminated up to 75 percent of the total candidates otherwise qualified. This high rate of rejection has since been reduced by a more detailed early selection procedure.[15]

Soviet officials have never released information about the total number of cosmonaut candidates evaluated as opposed to the number accepted into training. Indeed, with the exception of the Apollo-Soyuz cosmonauts, Soviet trainees seldom receive any visibility so that they are virtually unknown until after they have participated in a flight. However, German Titov, who piloted Vostok 2, is quoted as stating that in the 1960's, 51 men were selected for initial physical fitness training, of which 12 were selected to become the nucleus of the manned program of the early and mid 1960's.[16]

As the size and capabilities of Soviet manned spacecraft change in the future, there will probably be additional modifications in the cosmonaut selection process. However, in his book, "The Cosmonaut as a Researcher", cosmonaut N. Rukavishnikov (test-engineer on Soyuz 10 and 16) speculates that two basic categories of cosmonauts will continue to be selected for multi-manned orbital laboratories and interplanetary spacecraft. The first category will consist of the command crew responsible for the flight and will be made up of pilots, on-board engineers, navigators, communications specialists, and doctors. The second category will consist of scientific and technical specialists selected for specific missions peculiar to the flight program. Thus, there

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[13] Khilov, K. L. Some problems of evaluating the vestibular function of aviators and cosmonauts. Space Biology and Aerospace Medicine (USSR), No. 5, 1974. 47–52.
[14] DeHart, R. Biomedical Aspects of Soviet Manned Spaceflight. Op. Cit. 32.
[15] Link, M. M. et al. Selection of Astronauts. In: Foundations of Space Biology and Medicine. Op. Cit.
[16] Caidin, M. Red Star in Space. The Crowell-Collier Press, 1963, p. 212–213.

will likely be more changes made in the selection of specialty profiles than in the biomedical selection process itself.[17]

B. THE TRAINING PROCESS

1. General Protocol

In the early phases of the Soviet manned spaceflight program, the Soviet Air Force was responsible for cosmonaut training under General Nikolai Kamanin, who until recently headed that program.[18] The first formal training site was located at Frunze Airport on the outskirts of Moscow. In early 1960, the program was shifted to the new specialized facilities at Zvezdnyy Gorodok (Star Town) which is now the center for all cosmonaut training (also known as the Gagarin Cosmonaut Training Center). Secondary, specialized training facilities are scattered throughout the U.S.S.R. These include a number of high altitude military stations in mountainous regions which are used for acclimatization to hypoxia (decreased oxygen) and general physical conditioning, various locations along the Black Sea which are used for underwater (simulated weightlessness) training,[19] and even Soviet Antarctic bases, such as Vostok which are used for stress physiological research of relevance to the space program.[20-22]

The basic principle adhered to in Soviet cosmonaut training program, as in the U.S. astronaut training program, is that each crew member must be able to control the spacecraft, to service the regular systems of the vehicle, to carry out basic missions during the flight and to land the spacecraft. At the same time, each crew member must be sufficiently specialized to carry out specific flight missions. The training program therefore satisfies mission specialization while assuring that the cosmonaut has a knowledge of a wide range of disciplines.[23]

The fundamental Soviet philosophy for training cosmonauts is to design training curricula which exceed the physiological and psychological limits of the trainee and all situations anticipated in the space mission. To this end, there are distinct phases in the training program. The first involves general preparation which is administered to trainees who have not previously flown a mission. Here, the trainee is administered lectures and examinations on such subjects as the mechanics of spaceflight, space navigation, general principles of the spacecraft, astronomy, geography, meteorology, space biology, and medicine.[24]

The next phase involves technical preparation. This phase begins after crews have been established for a particular mission. The crews are familiarized with specific features of the mission through studies in the form of lectures and seminars with examinations which are con-

[17] Rukavishnikov, N. The Cosmonaut as a Researcher. Op. Cit.
[18] Link, M. M. et al. Training of Astronauts. In: Foundations of Space Biology and Medicine. Vol. III, Part 4, Ch. 16. Washington, D.C., NASA, 1975 (in press).
[19] Parin, V. V. Some important problems of space physiology. Aerospace Medicine, No. 9, 1969, p. 1011.
[20] Antoschenko, A. et al. At first in the water-then in space. Aviatsiya Kosmonavtika (USSR), No. 10, 1968, 75–77.
[21] Unsigned. Aviatsiya i Kosmonavtika (USSR), No. 4, 1973, p. 45 (Library of Congress, FRD 1280).
[22] Unsigned. A day at the Cosmonaut Training Facility. Sotsialisticheskaya Industriya (USSR), 8 April 1973, p. 4.
[23] Rukavishnikov, N. et al. The Cosmonaut as a Researcher. Op. Cit. p. 45–50.
[24] Ibid.

ducted by leading specialists in various spacecraft systems. In addition, practical studies are conducted with the cosmonauts at fabrication sites, and test and simulation facilities. The crew participates in the design of various systems, the compilation of flight programs, onboard flight documentation, and various technical conferences.[25]

In the flight-preparation phase the crew is exposed to various types of trainers and devices simulating programmed space operations. The number of devices involved in pre-flight preparation numbers several dozen. This phase also involves day and night parachute jumps from various types of aircraft, under various meteorological conditions, and in various types of terrain including deserts, mountains, and water. The most important feature at this stage is training on what the Russians refer to as the "complex trainer".[26] This is an exact model of the spacecraft in which it is possible to simulate all control, signal, and indicator systems.[27] The pilot is also able to observe a simulated environment outside the spacecraft including the Sun, the stars, and the Earth's surface. The crew simulates all basic operations to be performed during the flight, from launch to landing.[28]

The Russians consider the medical and biological preparation of the cosmonauts to be a separate phase of training. Here, trainees receive periodic examinations in special trainers and their behavior is examined under the influence of various uncomfortable conditions or "medical preparations". Emphasis is placed on preparation for long duration spaceflight. To this end, trainees exercise in special weight-loaded suits, and conduct various other physical exercises. At this stage, the final medical check and examination is given. The biomedical training program will be discussed in more detail below.[29]

An additional important phase of training involves preparation for the scientific and technical experiments of the flight. At this point, the cosmonauts come into close contact with scientists who have designed the experiments. They perform simulated protocols in trainers, attend lectures, visit various scientific organizations and observatories, and compile and formulate the onboard documentation of data.[30]

Finally, the crew performs a mockup of the flight in the "complex trainer" which lasts from several hours to more than a day and includes all of the major features of the flight. All flight conditions are simulated as completely as possible. This phase is under the guidance of a state commission which verifies that all flight procedures and systems are correct for final flight clearance. Inaccuracies simulating possible flight failures can be introduced and the crew is obliged to record these and spontaneously devise methods for controlling them. After successfully completing the mockup and passing examinations in all of the necessary disciplines, the state commission grants clearance for the flight.[31]

The Russians have continued to upgrade the cosmonaut training center. In 1972, a new training complex with modern equipment was

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[25] Ibid.
[26] Ibid.
[27] Khrunov, Ye. et al. Man-Operator in Space. Moscow, 1974, p. 297–306 (NASA TT F–15, 174).
[28] The cosmonaut prepares for flight, Kryl'ya Rodiny (USSR), No. 2, 1974, 10–14 (FRD #2066).
[29] Rukavishhnikov, N. The Cosmonaut as a Researcher. Op. Cit.
[30] Ibid.
[31] Ibid.

added so that now it includes a new centrifuge, spacecraft docking mockups, and Soyuz and Salyut trainers.[32]

While there are fundamental similarities between the United States astronaut and Soviet cosmonaut training programs, there are also some major differences. For example, according to cosmonaut A. A. Leonov of the ASTP crew, American astronauts have more flight training while Soviet cosmonauts heavily emphasize parachute jumping under a variety of situations. There is no formal or mandatory physical conditioning program for American astronauts who carry out physical training independently. This is in marked contrast to a mandatory and rigorous program of physical training for Soviet cosmonauts. The ASTP program has offered a unique opportunity to compare the relative merits of two training programs in detail.[33]

2. Vestibular Training

Since the flight of Vostok 2 in 1961, in which cosmonaut Titov experienced transient episodes of disorientation and nausea, the Russians have placed heavy emphasis on the vestibular training. This training involves both passive and active exercises designated to increase the resistance of the vestibular apparatus (inner ear) to the various linear and angular accelerations associated with spaceflight. The Soviet emphasis on the vestibular system is particularly evident in the research literature which will be discussed in a subsequent section.[34] But it is also evident in various recent accounts of cosmonaut training.[35] [36]

Prior to the training cycle, vestibular stability and sensitivity are evaluated on an individual cosmonaut basis. The protocol of the subsequent vestibular training program is therefore tailored to the vestibular profile of the cosmonaut.[37]

The category of "active" vestibular training is characterized by strenuous gymnastics and a number of sports which are known to stimulate the vestibular system. A variety of devices are used including the Loping swing (a rigid, standing, vertically rotating swing), trampoline, and a large wire-mesh drum which the trainee can rotate violently through a number of planes. Acrobatic exercises including swimming, scuba diving, running, and figure skating and ballet, are also commonly employed. Incorporated into these regimens are various standardized body and head movements designed to selectively stimulate the vestibular system such as somersaults, various head and trunk movements, and jumping exercises which require total-body rotation through 90, 180, or 360 degrees. Parachute jumping (including free fall) and simulated weightlessness training in a water-filled drum is also included in the category of active vestibular training.[38]

Passive vestibular training, on the other hand, does not require the active muscular participation of the cosmonaut. Rather, it is a mechanical type of training in which the cosmonaut sits or is strapped

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[32] "Prospects for manned spaceflight and life sciences in the Soviet space program according to 'Astronautics Day' discussions." Pravda. April 12. 1973. p. 3. (FRD #1239).

[33] Unsigned. Apollo-Soyuz joint flight training. Sovetskaya Rossiya (USSR), 28 July 1974, p. 3. (FRD #1944).

[34] Nikolayev. A. Space-Road Without End. Moscow. "Molodaya Gvardiya" Press, 1974. p. 42–46 (FRD #2186).

[35] Unsigned. Cosmonaut Training. Sovetskaya Estoniya (USSR), Dec. 6, 1974, p. 3 (FRD #2183).

[36] Unsigned. The cosmonaut prepares for flight. Kryl'ya Rodiny. No. 3, 1974, 10–13 (FRD #2067).

[37] Nikolayev, A. Space-Road Without End. Op. Cit.

[38] Ibid.

to a chair or other device which is mechanically rotated or agitated. Devices used for this training include: 1) the "universal rotating chair" which is mechanically rotated around its vertical axis in various horizontal planes and at various angular rates. This device exposes the cosmonaut to both angular and Coriolis accelerations; 2) the "floating" chair, a mechanically rotated chair which is suspended above the floor by four compressed air jets. In this device, the head and upper torso movements of the cosmonaut must be applied to maintain the system in a state of relative equilibrium; 3) the Khilov or parallel swing (named after its inventor, a famous Soviet vestibular physiologist) which is a platform suspended by four bars which swings back and forth without changing vertical position; and 4) the "optokinetic drum", a vertical rotating drum with black and white stripes painted on the interior surface. Inside the drum is a rotating chair which can turn independently or in synchronism with the drum. The object of this device is to link the functions of the visual and vestibular systems.[39]

All of these vestibular training approaches are claimed to improve measureably the stability and function of the vestibular system of cosmonauts, at least under terrestrial conditions. However, what remains unclear is whether this rigorous training regimen has really improved the cosmonaut's tolerance of actual spaceflight conditions. For the problem of transient cosmonaut disorientation during spaceflights has stubbornly persisted, as it has throughout the American Apollo series of flights. Therefore, it is difficult to evaluate the practical merits of the Soviet vestibular training program which has consistently been far more rigorous than its counterpart American program.[40]

The Russians continue to evaluate and modify vestibular training regimens. Efforts have recently been made to compare the efficacy of active and passive training methods and a combination of the two. It was found that all types of vestibular training improve the accuracy of spatial orientation. The passive method, using linear accelerations, appears to yield the best results. Oddy enough, a prolonged course of training (9 months) in which both passive and active methods were employed appeared to worsen the various indices of spatial perception.[41]

3. Visual training.

Most formal visual training is in the form of spatial orientation or passive vestibular tests such as the previously mentioned optokinetic drum. But there is some concern about possible decrements in visual function under spaceflight conditions. Accordingly, the Russians continue to explore more accurate and definitive methods of determining and forecasting visual function in space crews. A recent approach which has been investigated involves the measurement of psychophysiological factors (light and contrast threshold sensitivity) and general visual acuity (the perception of geometric, astronomic, and other photometric factors). As proposed, measurements could be made under normal laboratory or field simulation conditions. The procedure would be rapid (5 minutes) and testing devices would be light and

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[39] Ibid.
[40] Ibid.
[41] Yakovleva, I. Ya. et al. The function of perception of spatial coordinates by active, passive, and combined methods during vestibular training. Space Biology and Aerospace Medicine (USSR), No. 5, 1974, 60–66.

compact. Two devices would be used: one would be a focusing pattern chart to measure visual acuity; the other would be designed to measure visual contrast sensitivity. Thresholds of visual perception would be plotted as a function of the time required to complete the tests. Apparently the approach holds promise of finding practical application, since it has been tested successfully by Soviet bioastronautics experts during aircraft flights, during parachuting, and in simulators.[42]

4. Acceleration Training

Both the Soviet cosmonaut and the American astronaut programs employ centrifuge training to prepare flight crews to withstand acceleration forces associated with the launch and reentry phases of spaceflight. Cosmonaut trainees are exposed to transverse accelerations of up to 12 times the Earth's gravity (12 G).[43]

Exposure to the centrifuge is a gradual process. In the early phases of the Soviet spaceflight program, cosmonauts were exposed over a two month period to gradually increasing forces, starting with 2G and increasing in small increments to 10 or more Gs. A more recent variation of this training involves physical exercises prior to exposure. Using this approach, the total number of exposures has been approximately halved. With either approach, the increase in acceleration tolerance varies from 1.9 G to 3.2 G. Acceleration forces most commonly experienced by cosmonauts are in the 7–10–G range. The Russians claim that centrifuge conditioning is most effective in cases where initial tolerance of acceleration is low. The most effective approach is to gradually increase the G-load while simultaneously increasing the time intervals between rotation.[44]

There are apparently several man-rated centrifuges in the Soviet Union. Recent modern additions to the Soviet centrifuge inventory are of Swedish manufacture. The firm ASEA most recently provided the Soviet Union with a centrifuge with an 82 foot long boom which can generate acceleration forces of up to 30 G at 36.8 revolutions per minute (rpm). The test cabin has three axes of movement and is equipped with humidity, temperature, and pressure controls. Medical monitoring equipment will measure up to 60 physiological functions during rotation.[45]

5. Weightlessness Training

While true weightless conditions are impossible to simulate on Earth, it is possible to attain brief periods (up to about one minute) of weightlessness in high speed (jet) aircraft which fly through a parabolic (Keplerian) trajectory.[46] Soviet cosmonauts as well as American astronauts have continued to use this technique for short-term weightlessness training in preparation for spaceflights.[47] Other

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[42] Ivanov, Ye. A. Methods of studying operator vision functions in small flight vehicle cabins. Izvestiya Akademii Nauk USSR. Seriya Biologieheskaya, No. 5, 1973, 647–657 (FRD #1433).

[43] Stepantsov, V. I. et al. Basic principles for formulating training programs on a centrifuge. Space Biology and Medicine (USSR), No. 6, 1969.

[44] Link, M. et al. Astronaut Training. Op. Cit.

[45] Aviation Week and Space Technology, July 15, 1974, p. 17.

[46] Kopanev, V. I. et al. Physiology of the sensory sphere of man under the conditions of space flight. Moscow, Academy of Sciences USSR. 1972, 79 p. (NASA TT F–14, 530).

[47] Khachatur'yants, L. S. et al. In Open Space. Moscow, "Znaniye" Publishing House, 1973, 64 p. (FRD #1378).

approaches include immersion in water, including diving, free-fall parachute jumping, training on a special apparatus which simulates a support-free state, and prolonged bed rest and confinement.[48, 49]

As is typical of linear and angular accelerations, human tolerance of weightlessness is subject to considerable individual variation. Some Western observers have noted that up to 50 to 60 percent of subjects exposed to brief periods of weightlessness during parabolic flights have experienced vertigo and nausea. Many of the subjects had no flying background. On the other hand, of 39 Russian flyers exposed to such flights, only one experienced unpleasant sensations.[50]

It has been established that there are three general categories of individual response to short-term weightlessness: 1) No response or sensations of euphoria and well-being; 2) illusory sensations after 12 to 15 exposures; and 3) symptoms of discomfort experienced immediately upon exposure with subsequent difficulty in adapting to the factor. In the early phase of the Soviet spaceflight program, individuals in the third category were commonly eliminated from the training program. Later, it was discovered that most persons, even those with initially low tolerance, gradually adapt to this factor so that they presumably need not be eliminated from further training.[51]

Short-term weightlessness training by cosmonauts takes place both in small, single or two-seat aircraft as well as in large, multi-engined aircraft such as the TU–104.[52] The larger aircraft are called "flying laboratories" wherein fully outfitted cosmonaut trainees can simulate actual spaceflight situations such as extravehicular activities (EVA). Soviet cosmonauts are exposed to as many as 30 such flights. One Soviet cosmonaut reportedly completed 350 hours of total flying time (including weightlessness training) and conducted more than 100 parachute jumps.[53]

The more experimental aspects of the problem of weightlessness simulation will be discussed in the section devoted to acceleration and weightlessness.

6. Physical and Survival Training.

The physical training program for Soviet cosmonauts includes both mandatory and voluntary regimens, whereas in the United States astronaut program, physical training is purely voluntary. The various mandatory exercise regimens for cosmonauts are designed to increase tolerance of specific spaceflight factors. For acceleration tolerance, gymnastics and exercises on special equipment such as the Loping swing (a vertically rotating swing) and trampoline are conducted. To increase vestibular tolerance, there are midriff strengthening exercises, various acrobatics, swimming, and exercises on swings and revolving chairs. For hypoxia training, there is track, cross-country skiing, and swimming. Competitive sports of the cosmonaut's preference such as basketball, handball, and wrestling are said to develop emotional stability and concentration.[54]

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[48] Nikolayev, A. Space-Road Without End. Op. Cit. p. 47.
[49] Link, M. and N. N. Gurovskiy. Astronaut Training. Op. Cit.
[50] Kopanev, V. I. Physiology of the sensory sphere of man under the conditions of spaceflight Op. Cit.
[51] Link, M. et al. Astronaut Training. Op. Cit.
[52] Ibid.
[53] The flight of the manned scientific station Salyut 3, Aviation and Cosmonautics (USSR). No. 8, 1974, 6–7 (FRD #1983).
[54] Makarov, R. Flight demands training. Aviation and Cosmonautics (USSR), No. 2, 1974, 44–45. (FRD #1662).

The Russians also stress high altitude (mountain) adaptation and parachute jumping as important adjuncts to the physical training program. It is felt that high altitude training increases resistance to accelerations and hypoxia and increases physical work capacity. Moreover, high altitude training facilities are convenient for the psychological training of crews under adverse conditions.[55]

More recently, cosmonaut candidates have undergone survival training in the desert and in the Indian Ocean. Groups of cosmonauts with accompanying physicians were provided with survival kits and sufficient rations for one-fifth the daily intake of food and water. Medical examinations were conducted daily and the survival tests were continued for an unspecified length of time until the health of the subjects appeared to be endangered.[56]

7. Behavioral and Simulator Training.

In the early days of the Soviet manned spaceflight effort, space psychology, like the social and psychological sciences in general, was looked down upon as a non-science. A prominent Soviet space life scientist was once quoted as proclaiming in a private conversation that space psychology was somewhat akin to the "rubbing of one's navel against infinity".[57]

Since that time, the behavioral aspects of manned spaceflight have assumed increasing relevance. The terms "psychology" and "psychophysiology" are now commonly encountered in virtually all aspects of the Soviet manned spaceflight program, from the theoretical to the practical. Psychological or behavioral preparation is linked to every facet of the cosmonaut training program. Marxist-Leninist studies as well as physical conditioning are considered to contribute to the moral and psychological development of the cosmonaut. Space psychology is now defined to include all aspects of man-machine interaction as well as investigations of group compatability. Activities which are considered to promote psychological preparedness for spaceflight include the piloting of various aircraft, particularly in groups; parachuting, including free-fall; water immersion and diving; acrobatics; pressure and heat chamber training; centrifuge and vestibular training; isolation and confinement; work-rest training; and, in general, all phases of cosmonaut training discussed in this section.[58]

Cosmonauts are under psychological scrutiny from the selection process throughout the spaceflight itself. Their behavior patterns are evaluated for each new situation encountered in the training cycle. In addition, the group compatability of each Soviet crew has been evaluated in detail throughout the Soyuz-Salyut program.[59]

Dr. Yu. A. Senkevich, who participated in both the Heyerdahl (Ra) expeditions, investigated the compatability of international crews as it relates to cosmonautics. He concluded that although disagreements and "clique" formation are inevitable, they can be minimized by a scientific approach to group selection, particularly the group leader. Selection should be based on professional qualifications and particu-

[55] Link, M. et al. Astronaut training. Op. Cit.
[56] Volovich, V. Soviet cosmonaut survival training. Aviation and Cosmonautics (USSR), No. 12. 1973. 38–39.
[57] Mandrovskiy, B. Personal communication, 1965.
[58] Nikolayev, A. Moral and psychological training for cosmonauts Aviation and Cosmonautics (USSR), No. 3, 1974, 40–41 (FRD #1717).
[59] Cosmonaut psychology. Literature Gazette (USSR), July 17, 1974, p. 1;10 (FRD #1939).

larly the individual's ability to relate to others. Special training can enhance the latter quality.[60]

One of the classical approaches to the psychological preparation and evaluation of cosmonauts has been isolation, confinement, and restricted activity (hypokinesia and hypodynamia) training. This has been carried out in the so-called "Chamber of Silence", a soundproof (anechoic) chamber in which the trainee is obliged to spend days at a time in strict isolation. This solitary confinement and relative inactivity is designed to test the psychophysiological and emotional stability of the subject. During the exposure, the trainee lives and works an altered work-rest cycle corresponding to the anticipated spaceflight mission. Exposure times have ranged from 7 to 15 days for cosmonauts who participated in the Vostok program. Medical and psychological data are gathered throughout the exposure with emphasis on functional and behavioral changes caused by the experiment. Thus far, it has been concluded that all trainees have exhibited a high level of emotional and psychological stability and have adapted well to the various stresses. Special sets of physical exercises, including isometrics and exercises conducted with the aid of a bicycle ergometer and rubber expanders have been incorporated into the spaceflight program.[61]

Simulator training also falls within the sphere of psychophysiological preparation. Table 4–3 shows the various types of training devices from which psychophysiological data is derived and demonstrates, once again, that behavioral observations are incorporated into virtually all phases of the cosmonaut training program.[62]

TABLE 4-3.—SOVIET TRAINING DEVICES FOR CONDITIONING THE OPERATIONAL HABITS OF COSMONAUTS

Dynamic simulators, Functional simulators	Specialized simulators	Fixed simulators, Complex simulators
Spacecraft instruments and other systems.	Control of life support (ecological) systems.	Space station.
Manual control	Approach, mooring, and rendezvous with other objects or spacecraft.	Multimanned spacecraft.
Life support system	Landing and takeoff from the moon, Mars, and other planets.	1-man spacecraft.
Optical equipment	Specialized systems (EVA)	
Radio equipment	Piloting and navigation	

SOURCE: Leonov, A., et al., Psychclogical features of the activities of cosmonauts; Moscow: Navka Press, 1971, pp 54–66.

In the opinion of P. V. Simonov, a specialist in space-crew psychology, simulator training in which malfunctions are programmed and special training for the most probable emergency situation should be viewed as the most important aspects of the cosmonaut training program and the most effective way of preventing neuroemotional stress. The development of skills should reach such a degree of perfection that optimum performance should be assured in the absence of confirmatory feedback. As expressed by cosmonaut Khrunov:

> Sometimes it happens that a certain individual does everything completely correctly, but he is found to seek confirmation that this is true. If there is no such feedback, he becomes confused and begins to make mistakes. Another in-

[60] Psychological compatability of international crews. Medical Gazette (USSR), April 12, 1974, p. 4 (FRD #1767).
[61] Link, M. M. et. al. Astronaut training. Op. Cit.
[62] Leonov, A. et. al. Psychological Features of the Activity of Cosmonauts. Moscow. "Nauka" Press, 1971, p. 54–66.

dividual does not require such feedback. This confident individual is the future spacecraft commander.[63]

Recently, the Russians have been investigating the dynamics of voice patterns as an indicator of neuroemotional stress. Various elements of speech (intensity, stress point, word order etc.) are analyzed as an index of the cosmonaut's psychological and physiological state. The effects of various flight factors on voice dynamics are evaluated so that they can be later correlated with actual spaceflight situations. Speech profiles are established during the initial period of cosmonaut training. Specially trained listeners monitor the cosmonaut's voices and their analyses are recorded and re-analyzed in a computer to obtain the most objective evaluation. Initially, an attempt was made to analyze voice patterns directly by computer. However, this method proved to be slow. Investigations on this subject continue.[64,65]

In summary, the Russians are continuing to develop more accurate quantitative methods of assessing and predicting cosmonaut behavior and performance. Multifaceted analyses are being developed. Flight-related factors such as task complexity, duration and complexity of the flight program, task compatability with equipment, habitability factors, and work-rest cycles are being evaluated. Personal factors such as background, health and emotional status, and psychophysiological characteristics are also being assessed. The quality of performance is evaluated as a function of error, accuracy and efficiency of work, and time required to complete the task. Quantitative factors continue to be developed. Once developed, probability parameters may be applied to the design of various man-machine systems as well as to spaceflight missions and associated training programs.[66]

III. Space Medicine

A. MEDICAL MONITORING

Biomedical information was first transmitted to Earth from a spacecraft during the November, 1957 flight of the dog, Layka, in Sputnik 2. During this one week flight, certain vital functions such as heart and respiration rate were monitored. This and subsequent biological space missions demonstrated that higher vertebrates could successfully withstand various spaceflight factors such as weightlessness and paved the way for the first manned missions of the early 1960's.[67]

Since the very first Vostok flight in April, 1961, Soviet efforts to monitor the medical status of cosmonauts have become more elaborate. But certain basic parameters monitored have remained constant. Thus, physical parameters vital to cosmonaut health have included: temperature; humidity; atmospheric pressure; and the oxygen and carbon dioxide content of the spacecraft atmosphere. Medical parameters have included: continuous heart rate; pneumography (lung function); electrocardiography; seismocardiography; electroencephalo-

[63] Simonov, P. V. Psychophysiological Stress of Spaceflight. Moscow. Academy of Sciences USSR, 1972, 63 p. (NASA TT–F–14,863).
[64] Cosmonaut psychology. Op. Cit.
[65] Ushakov, A. Listening to the cosmonaut's voice. Kazakhstanskaya Pravada (USSR), Feb. 22, 1974, p. 4 (FRD #1695).
[66] Lebedev, V. et al. Indices of pilot-cosmonaut work quality during spacecraft control. Space Biology and Aerospace Medicine (USSR), No. 6, 1974, 42–45.
[67] U.S. Congress. Senate. Committee on Aeronautical and Space Sciences. Soviet Space Programs, 1966–1970. Wash., D.C., U.S. Govt. Printing Office, 1971, p. 258.

graphy; electrooculography; electromyography; thermography; and galvanic skin response.[68] Voice transmission and television have been available from the earliest Vostok flights for psychological analysis. Not all of the medical parameters listed above have received the same emphasis on every flight and each manned mission has been characterized by emphasis on some particular facet of cosmonaut health and performance during the flight.[69]

Like the American astronauts, the medical monitoring of cosmonauts is initiated during the selection process, proceeds through the training process and the flight itself, and continues long after the flight is terminated. During the flight, various medical conditions are compared with pre-flight data. The function of medical specialists during a given manned flight is to compare the cosmonaut's current physical condition with his condition prior to the flight in order to attempt to predict his future medical status. Thus, the medical specialist has become intimately familiar with the cosmonaut's medical status over a long period of time and only those specialists involved in the cosmonaut's selection and training participate in medical monitoring and data analysis during the flight. The Russians are presently attempting to develop a variety of mathematical, clinical, and physiological approaches with which to better predict the condition of cosmonauts during a given mision.[70]

Throughout the Soviet manned spaceflight program and especially during the Soyuz portion of that program, medical monitoring has been specially formulated to assess the various effects of the weightless state on cosmonauts.[71] Extensive examinations of the condition of the central nervous system, cardiorespiratory system, metabolism, blood chemistry, and water-electrolyte balance have been conducted before and after the flights.[72] Peripheral blood composition was studied before and after the flights of Soyuz 9 and Soyuz 11/Salyut 1.[73] [74] Lower-body-negative-pressure (LBNP) has been used to evaluate the conclusion of cardiovascular systems of cosmonauts before, during, and after spaceflight since the Soyuz 11/Salyut 1 mission.[75] [76] [77] As Soviet manned space misions have become longer and more complicated, the cosmonauts themselves have been obliged to assume greater responsibility for carrying out a variety of medical tests which are used to evaluate their condition during the flight.

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[68] Parin, V. V. et al. Soviet research in space medicine. Aerospace Medicine. No. 3, 1974, 339–340.

[69] Bayevskiy, R. M. Physiological Measurements in Space and the Problem of Their Automation. Moscow. "Nauka" Publishing House, 1970, p. 5–66 (FRD #2243)

[70] Izvestiya. Feb. 8, 1975, p. 5 (FRD #2232).

[71] Kakurin, L. I. Medicobiological investigations based on the Soyuz flight program. Vestnik of the Academy of Sciences USSR, Feb., 1972, 30–39.

[72] Parin, V. V. et al. Soviet research in space medicine. Op. Cit.

[73] Legenkov, V. J. Variations in the composition of the peripheral blood of cosmonauts during 18 and 24 day spaceflights. Space Biology and Aerospace Medicine (USSR), no. 1, 1973, 39–44.

[74] Mandrovsky, B. N. Soyuz-9 flight, a manned biomedical mission. Aerospace Medicine, No. 2, 1971, 172–177.

[75] Gurovskiy, N. N. et. al. Some results of medical investigations carried out on the orbiting scientific laboratory, Salyut. Aerospace Medical Association, 43rd Annual Meeting, 1972. 13 p. (unpublished).

[76] Major medical aspects of the flight of the Soyuz 12 spacecraft. 1973, 15 p. (unpublished).

[77] Degtyarev, V. A. et al. Results of examining the Salyut crew during LBNP tests. Space Biology and Aerospace Medicine (USSR), No. 3, 1974, 47–52.

B. MEDICAL INSTRUMENTATION AND BIOTELEMETRY

As medical monitoring programs during spaceflights have become more complicated and demanding, the need for sophisticated medical instrumentation has increased. Therefore, the rather primitive medical instrumentation used in the early biosatellites and Vostok series of manned flights has evolved into equipment which has been designed for flexibility, utility, and accuracy of data sensing. For example, electrocardiogram electrodes used in the early Vostok flights were pasted onto the skin whereas now they can be emplaced with tape. Similarly, EEG electrodes are now mounted in a helmet rather than pasted onto the skin. Seismocardiography, which provides data on the force, rhythm, and ejection of blood from the heart into major blood vessels, was first used on Vostok 5 and is now standard equipment in the Soyuz/Salyut series of vehicles. New instruments have also been developed to measure blood circulation in the head. In general, medical monitoring equipment has become more compact, more reliable in operation, and simpler for the cosmonaut to use.[78]

The biomedical monitoring programs of Soviet and United States manned spaceflight and biosatellite missions since 1957 is provided in Table 4–4.

TABLE 4–4.—BIOMEDICAL MONITORING ON SOVIET AND UNITED STATES SPACECRAFT, 1957–75

Spacecraft, biosatellites, and year of launch	Physiological measurement methods	Features of onboard medical equipment and biotelemetry systems
2d Soviet Earth satellite (1957)	Electrocardiography, pneumography; arterial oscillography, actography.	Equipment was turned on with a programmed device.
2d–5th Soviet spacecraft satellites (1960–61).	EKG; pneumography; phonocardiography; sphygmography, electromyography, actography; arterial oscillography; body temperature reading; seismocardiography.	Commutator for successive measurement of slowly changing parameters, electrocardiophone.
Vostok spacecraft (1962–65)	EKG; pneumography; seismocardiography; kinetocardiography; electrooculography; EEG; galvanic skin reflex.	Placement of preamplifiers in cosmonauts' clothing; multipurpose use of amplifie channels.
Mercury capsules (1962–65)	EKG; pneumography, arterial pressure; body temperature readings.	Automatic arterial pressure reading; system of EKG and impedance PG tracing using common electrodes.
Voskhod spacecraft (1964–65)	EKG; PG; seismocardiography; EEG; electrodynamography; motor acts of writing.	2 units: medical monitoring and medical examinations; special medical monitoring panel actuated upon going into orbit.
Soyuz spacecraft (1967–75)	EKG; PG; seismocardiography; body temperature.	Special medical monitor panel for recording body temperature and pulse while going into orbit.
Gemini spacecraft (1965–67)	EKG; impedance PG; arterial pressure; body temperature; phonocardiography, EEG.	Use of special onboard tape recorder for medicophysiological parameters.
Kosmos 110, artificial Earth satellite (1966).	EKG; sphygmogram; seismo-cardiogram; aortic pressure.	Electric stimulation of receptor zones of carotid sinus using a programed device; automatic administration of pharmacological agents.
Apollo spacecraft (1968–72)	EKG; impedance PG	Upon exit on the Moon's surface pulse rate was retranslated in the lunar module and through its telemetry system to Earth.
Biosatellite 3 (1969)	EKG; impedance PG; EEG; changes in blood pressure by catheterization of pulmonary vessles; arterial and venous system; brain temperature with implanted sensors; study of behavioral reactions.	Automatic analyzer of calcium, creatine, and creatinine in urine; special biotelemetry device with 10 channels operating at an access speed of 100/sec and one "slow" channel (10/sec).

[78] Bayevskiy, R. M. and W. R. Adey. Methods of Investigation in Space Biology and Medicine: Transmission of Medical Data. In: Foundations of Space Biology and Medicine, Vol. II. Part 5., Ch. 18, Washington, D.C., NASA, 1975. pp. 668–706.

TABLE 4-4.—BIOMEDICAL MONITORING ON SOVIET AND UNITED STATES SPACECRAFT, 1957–75—Continued

Spacecraft, biosatellites, and year of launch	Physiological measurement methods	Features of onboard medical equipment and biotelemetry systems
Kosmos 605 Biosatellite (1973)	Motor activity of small animals (rats)	Noncontact transducer and radiotelemetry.
Salyut orbital stations (1971–75)	EKG; PG; seismocardiography; kinetocardiography; sphygmography of femoral artery; arterial pressure tachooscillographic method.	On-board tape recorder to record data; special unit of medical research equipment (Polinom-2m).

SOURCE: Bayevskiy, R. M. and W. R. Adey in Foundations of Space Biology, vol. II, pt. 5., ch. 18 Washington, D.C., NASA 1975 pp. 668–706.

Note: The operating characteristics of biomedical monitoring systems for short-term, long-term, and interplanetary manned spaceflights are summarized in Table 4–5.

TABLE 4-5.—CHARACTERISTICS OF BIOMEDICAL MONITORING SYSTEMS FOR DIFFERENT SOVIET MANNED SPACECRAFT MISSIONS

Short flights (up to 5 days)	Long flights (up to 1 month)	Interplanetary flights
During flight all sensors and electrodes are on the cosmonaut.	Only a minimum number of sensors and electrodes for medical monitoring are on the cosmonaut; most are applied by him for brief examination periods.	Sensors and electrodes of the medical monitoring system and all other sensors are applied by the onboard physician.
Cosmonaut is wired to onboard equipment.	Incabin radio lines are used for medical monitoring.	Incabin radio lines are used for medical monitoring.
Onboard medical equipment is controlled automatically from Earth or onboard programed device.	There is manual control in addition to automatic and programed.	The physician controls the equipment.
Physiological data are recorded only during periods of direct communication with land-based centers.	The bulk of physiological data is recorded by memory devices during periods without communication with Earth, with subsequent automatic transmission of all data to Earth.	Data are recorded by onboard devices with storage in processed form. Only a small part of summarized data is transmitted to Earth.
Physiological data are transmitted in the form of oscillograms.	Physiological data tramsmitted only partially in oscillogram form. Most data are transmitted in digital and summarized code form.	Physiological data are transmitted to Earth only in summarized form.

SOURCE: Bayevskiy, R. M. and W. R. Adey, Foundations of Space Biology, vol. II, chap. 18. Washington, D.C., NASA, 1975, pp. 668–706.

It is evident that the state-of-the-art of Soviet medical monitoring and associated bioinstrumentation is advancing rapidly. Electronic arrays capable of the rapid and simultaneous measurement of several physiological parameters are in the advanced stages of testing.[79] A number of computers are being applied to physiological and neuropsychological research.[80] [81] Methodology and instrumentation for monitoring and analyzing cardiovascular and brain function are being improved.[82] [83] Finally, quantitative methods for better predicting the physiological condition of the cosmonaut during space missions are being perfected.[84] [85]

[79] New Soviet "Express Monitor" of physiological indices. Medical Gazette (USSR), Oct. 26, 1973, p. — (FRD #1443).

[80] Chikhman, V. N. et al. Real-time operation of the Dnyepr-21 computer in a physiological experiment. Physiological Journal (USSR), No. 4, 1974, 644–647 (FRD #1857).

[81] KSIO–1 computer determines behavior during stress. Science and Life (USSR), No. 9, 1974, p. 75 (FRD #2059).

[82] Simonov, P. V. et al. Characteristics of the electrocardiogram during physical and emotional stress in man. Aviation, Space, and Environmental Medicine, No. 2, 1975, 141–143.

[83] Popenchenko, V. V. et al. Four-channel miniature radiotelemetric system for transmitting brain biopotentials. Journal of Higher Nervous Activity (USSR), No. 5, 1972, 1087–1089 (JPRS 58056).

[84] Bayevskiy, R. M. Predicting man's condition during spaceflight. Physiological Journal (USSR), No. 6, 1972, 819–827 (JPRS 57660).

[85] Gurovskiy, N. N. et al. Some theoretical aspects of formulating a system of medical control for space missions. Space Biology and Aerospace Medicine (USSR), No. 3, 1975, 34–37.

C. EXERCISE AND ASSOCIATED EQUIPMENT

As Soviet and American spaceflights have increased in duration from a few days to many weeks, space medicine specialists have become more concerned that prolonged exposure to weightlessness will have a variety of deleterious effects on the physical well-being of cosmonauts and astronauts. Of particular concern has been a deconditioning and degeneration (atrophy) of skeletal muscles, and most important, the cardiovascular system. The concern is a real one since it has been compellingly demonstrated that prolonged weightlessness as well as simulated weightlessness (bed-rest and hypodynamia experiments) lead to a deconditioning of both smooth and skeletal musculature as well as to changes in other bodily functions. Accordingly, Soviet medical specialists, like their American counterparts, have continued to formulate exercise regimens for cosmonauts which will hopefully prevent, or at least minimize the deconditioning process. Exercise regimens have therefore become more rigorous as the Soyuz/Salyut and Apollo/Skylab programs have progressed.[86 87 88]

The first prolonged Soviet manned spaceflight was the mission of the Soyuz 9 in June 1970. During that 18-day flight, physical exercises were performed by each cosmonaut for two one-hour periods every day. The exercises, formulated to enable the cosmonauts to withstand weightlessness and subsequent acceleration stress (re-entry) were designed to maintain high muscular, nervous system, cardiovascular, and digestive system tone. In order to maintain a sufficient load on major muscle groups in the absence of gravity, special elasticized garments were used, a practice which has persisted throughout the balance of the Soyuz/Salyut program. In addition, special springs were used to affix the body to the floor of the spacecraft with a tension of several kilograms, enabling the cosmonauts to simulate walking, running, and jumping in place. Chest expanders and a variety of isometric exercises were also used. Physiological parameters were monitored before and after exercise sessions to evaluate changes in work capacity and to relate physiological energy expenditure to the operation of the life support system. Curiously enough, this carefully graded exercise regimen did not at first produce the desired results, for both cosmonauts experienced considerable orthostatic stress and intolerance to Earth's gravity in the post-flight period which required several days of rest and readaptation to correct. A satisfactory explanation for this rather disturbing phenomenon was never determined, although it was speculated in American space medicine circles that the cosmonauts may have been over-conditioned prior to the flight. There was also some speculation that the relatively advanced age of one cosmonaut (41) may have contributed to the problem, although the other cosmonaut (aged 34) experienced essentially identical symptoms. Above all, there was apprehension in the space medicine community that man might not be able to withstand such a long exposure to weightlessness. However, it is interesting to note that neither American astronauts nor subsequent

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[86] Vorobyev, Ye. et al. Preliminary results of medical monitoring (Soyuz–6, 7, and 8). Medical Gazette, Jan. 23, 1970, p. 3.
[87] Berry, C. A. Medical legacy of Apollo. Aerospace Medicine. No. 9. 1974. 1046–1056.
[88] NASA doctors impressed at the physical state of astronauts. Washington Post, Sept. 27, 1973, p. A4.

Soviet cosmonauts have experienced similar difficulties after even longer duration spaceflights of up to 84 days.[89 90 91]

In the 24 day Soyuz 11/Salyut 1 flight, the three cosmonauts performed 2.5 hours of physical exercises each day. On the larger Salyut space station, the equipment available for physical exercises was more elaborate. For example, the cosmonauts were provided with a treadmill on which it was possible to walk, run, jump and perform a variety of other maneuvers. Once again, a special elasticized garment, called the "Penguin" suit, was provided to stress certain key muscle groups.[92] Finally, a special antigravity suit to counteract an anticipated disruption of circulation after re-entry was provided. Unfortunately, the cosmonauts were never to test these suits, for tragically, a valve linking the two compartments of Soyuz 11 stuck after they separated just prior to re-entry and all these cosmonauts perished. It was to be three years before the Russians attempted another prolonged mission to test the effects of their newly formulated exercise regimen and equipment. However, from all indications the Soyuz 11 cosmonauts were in good health prior to their fatal re-entry and the physical conditioning regimen evidently contributed to that condition. In other words, there were no reasons to believe that the cosmonauts would not have re-adapted successfully to Earth's gravity after their return.[93]

During the 15 day Soyuz 14/Salyut 3 mission of July, 1974, extensive physical exercises initiated in the second week of the flight were designed to assess the effect of physical conditioning on eventual re-adaptation to Earth's gravity. Once again, a treadmill was provided and a new variant of the special elasticized suit ("Penguin" suit) was tested. The suit was connected to the floor by elastic bands from the waist and shoulders to simulate gravitational stresses on major supporting muscle groups. Exercise sessions were scheduled at the beginning and end of each working day. When this exercise program was started after the fourth day in orbit, some evidence of re-adaptation to simulated gravity was noted, an indication that the program was conferring the desired results.[94 95]

During a longer mission, the 29-day Soyuz 17/Salyut 4 flight of January, 1975, the cosmonauts exercised three times per day for a total of 2.5 hours. Every fourth day, the selection of exercises was optional. In this mission, a bicycle ergometer was available which could be pedaled either with the hands or feet. An additional new approach to physical conditioning was electrical stimulation of various muscle groups using a special apparatus called "Tonus".[96] Presumably, a variant of this exercise program was continued during the Soyuz 18/Salyut 4 mission. Evidently, the exercise regimens formulated for Soviet cosmonauts and American astronauts have been suc-

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[89] Mandrovsky, B. Soyuz–9 flight. A manned biomedical mission. Op. Cit.
[90] Chirkov, V. A. Energy expenditures of the Soyuz–9 spacecrew during an 18 day flight. Space Biology and Aviation Medicine (USSR), No. 1, 1975, 48–51.
[91] Berry, C. A. Medical legacy of Apollo. Op. Cit.
[92] Umanskiy, S. P. Man in Space Orbit. Moscow, "Mashinostroyeniye" Press, 1974, p. 26 (NASA TT–F–15973).
[93] Gurovskiy, N. N. et al. Some results of medical investigations carried out on the orbiting scientific laboratory, Salyut. Op. Cit.
[94] Soviet Salyut–3 crew focuses on medical-biological tests. Aviation Week and Space Technology, July 22, 1974, p. 15.
[95] Spacemen keep in shape by "running" on Salyut. Washington Post. July 9, 1974, p. 4.
[96] Soyuz–17/Salyut–4: Daily routine and life support systems. Sources: Various Soviet newspapers, 22–24 Jan. 1975. (FRD #2196 and 2216).

cessful in minimizing physical deconditioning brought on by prolonged exposure to weightlessness.

New approaches to the problem of physical deconditioning in space continue to be developed. In order to prevent the unfavorable effects of weightlessness, A. S. Barer, a noted Soviet gravitational physiologist, recommends the use of a pressure suit which exerts axial pressure on the body and resists extremity movement. This approach to skeletal muscle conditioning would be yet another variant of the previously mentioned "Penguin" suit. Another suit recommended by Barer would impart negative pressure to the lower body (LBNP) for the purpose of conditioning the cardiovascular system.[97] In addition, methods to monitor and to electrically stimulate selected muscles, a form of biofeedback, are also being developed to complement physical exercise programs.[98]

At the same time, there is some evidence that the physical exercise and instrumentation approaches used in the manned spaceflight effort are finding some application in clinical medicine. For example, the treadmill used by the Soyuz 14/Salyut 3 cosmonauts is being used in a Soviet clinic to aid patients in exercising after long periods of complete bed rest.[99] This provides additional evidence that exercise programs and equipment designed for cosmonauts and astronauts are helpful in preventing deconditioning brought on by prolonged weightlessness or periods of inactivity.

D. MEDICATION AND EMERGENCY DRUGS

Compact drug kits have been carried aboard Soviet and American manned spacecraft since the early phases of both programs. In the space capsule series (Gemini, Apollo, Vostok, Voskhod, and the early Soyuz series (3–10)), a relatively limited supply of routine medications such as aspirin, antihistamines, sedatives, topical ointments, anti-motion sickness drugs and a few injectable drugs for emergencies were carried along. In the Soyuz 6, 7, and 8 flights, and presumably in the subsequent Soyuz 9 and 10 missions as well, it was reported that ground-control medical specialists were ready to render emergency "space" aid to the crew at any moment. For this purpose there was a drug kit which contained ingestable and injectable drugs. Fortunately, the Soyuz crews did not have occasion to use this kit.[100]

As the relatively short duration space capsule missions evolved into the longer orbiting laboratory missions of Skylab and Salyut, the problem of routine and emergency medication became more complicated. Therefore, the list of medications and emergency drugs increased so that the orbiting laboratories were essentially self-contained space pharmacies complete with a wide variety of ingestable, topical, and injectable preparations. One crew had the benefit of a physician (Skylab 2) so that the administration of medications was somewhat

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[97] Barer, A. S. et al. Physiological and hygienic substantiation for the design of individual measures to prevent the adverse effects of weightlessness. Space Biology and Aerospace Medicine (USSR), No. 1, 1975, 41–47.

[98] Young Technologist (USSR), No. 6, 1973, p. 23 (FRD #1347).

[99] Aviation Week and Space Technology. Sept. 23, 1974, p. 13.

[100] Vorobyev, Ye. et al. Preliminary results of medical monitoring (Soyuz 6, 7, and 8). Op. Cit.

simplified. During that 28 day flight anti-motion sickness pills, antihistamines, decongestant nose spray, and aspirin were used.[101]

Although none of the Soviet Salyut crews have had the benefit of an attending crew physician, a rather long list of medications and drugs have been carried along. These have included drugs and antacids for gastrointestinal disturbances, antinausea drugs, stimulants, first aid bandages and ointments, pain killers, tranquilizers and sedatives, cough medicine, antibiotics, and antiallergenic drug, a radioprotective drug and vitamin complex to be used only upon command from ground control, and nitroglycerine tablets for cardiac dysfunction. Injectable drugs have included atropine for acute nausea, caffeine for acute fatigue, cordiamine for weakened cardiorespiratory function, and promedol for severe pain.[102] Essentially the same list of drugs and medications have been carried aboard subsequent Salyut flights including the most recent Salyut 4 mission. A recent East German article includes a picture showing the Salyut 4 drug kit including disposable syringes containing the previously mentioned atropine, promedol, cordiamine, and caffeine. Beside each drug name are listed symptoms and instructions for administration.[103] Presumably, injectable drugs and the radioprotective drug are administered only after clearance from ground-control. Fortunately, there has been no occassion on either American or Soviet space stations in which the use of potent emergency drugs has been necessary.

E. NUTRITION

Although both American and Soviet space crews have traditionally complained about the poor palatability of space foods, the menu for space missions has steadily become more diverse since the early space-capsule series of flights. Foods available to American crews during the Apollo/Skylab series of flights have included freeze-dried rehydratables, thermostabilized foods, bite-sized cubes of either dried or moist food, and a variety of beverages. In Skylab 2, the crewmen reported that many of the foods tasted too bland. Accordingly, packets of spices such as tabasco sauce, horseradish, and onion and garlic powder were added to the menu. More than 110 food items were available by the end of the Apollo program. Hot and cold water was available for rehydration. The daily caloric intake for American astronauts has averaged about 2,500 calories. Although there has been some weight loss in all American and Soviet flights, it has not been due to a shortage of food.[104] [105]

The daily caloric intake for Soviet cosmonauts has ranged from 2,600 to 2,900 calories. Even in the first short Vostok flight of 1961, there was a fairly diverse menu. At that time, space food was provided in small, collapsible aluminum tubes containing approximately 160 grams of product and consisting of pureed items such as meat and vegetables, prunes, a variety of fruit juices, processed chocolate, and

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[101] Dr. Kerwin's log of Skylab 1. Medical World News, Sept. 7, 1973, 41–44. [Skylab 2 was the first manned visit to the Skylab 1 Station.]

[102] Gurovskiy, N. N. Some results of medical investigations carried out during the flight of the Salyut–1 orbiting scientific laboratory. Op. Cit.

[103] The captain has his (space) station (a description of the Salyut–4 training program). Free World (East Germany), No. 8, 1975, 1–7.

[104] Berry, C. A. The legacy of Apollo. Op. Cit.

[105] Dr. Kerwin's log of Skylab–1. Op. Cit.

coffee with milk. Some bite-sized solid foods included bread, smoked sausage, and candy.[106]

By the time of the early Soyuz flights, the cosmonaut's menu had become even more diverse. Unlike the earlier Vostok and Voskhod flights, the diet consisted of unadulterated foods individually tailored to the tastes of the cosmonauts. Included were several kinds of bread and pastries, meat, juices, and other items.[107]

On Soyuz 9, the crew was provided for the first time with an electric coil for heating food in special aluminum containers. The menu included soups and coffee, steak, pork chops, boned chicken, eggs, and a variety of other items. Fluid intake declined somewhat but remained within normal limits (1.6–1.8 liters per day). Water was treated with silver ions rather than chlorine in order to preserve taste quality.[108]

The food on the Soyuz 11/Salyut 1 flight consisted of an even greater diversity of canned, pureed, dehyrated, and natural foods many of which could be heated. Hot meals were enjoyed by the cosmonauts three times per day. The daily ration weighed 1,380 grams consisting of 154 grams of protein, 114 grams of fat, 307 grams of carbohydrates, and 760 grams of water for a total nutritional value of 2,950 calories. Polyvitamins and sweets were also included in the diet. Daily intake of water was 1.9–2.0 liters.[109] The diet on Soyuz 12 and subsequent Soyuz/Salyut missions was essentially similar to the above but with new items added each time to conform to the individual tastes of new crew members. Apparently, spaceflight conditions have commonly altered the tastes and appetites of cosmonauts. On Soyuz 12 as in some previous flights, there was a decline in appetite and thirst and an unfavorable reaction to some foods normally preferred on Earth. However, cosmonauts in the Soyuz/Salyut missions have received ample nourishment despite some small decreases in body weight.[110-112]

F. WORK-REST CYCLES AND BIOLOGICAL RHYTHMS

In man, about 40 physiological functions and reactions have been identified which roughly conform to a daily (circadian) pattern of activity. One of the classical functions is sleep and wakefulness which follows an approximate 8 hour/16 hour cycle which tends to be static for several days despite time-zone shifts. So-called "jet lag" is used to describe the temporary fatigue and physiological dysfunction which people experience when they travel significant distances in an east-to-west or west-to-east direction. Other vital functions exhibiting daily rhythmicity include body temperature, heart and respiratory function, brain activity, and a variety of metabolic functions. During a spaceflight, man is exposed to a dramatically altered light and dark cycle. In the course of a single day of orbital flight, an astronaut or cosmonaut, such as Titov in Vostok 2, will experience upwards to

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[106] Popov, I. G. Food and Water Supply. In : Foundations of Space Biology, Vol. III, Part 1, 1975 (in press).
[107] Vorobyev, Ye. et al. Preliminary results of medical monitoring (Soyuz 6, 7, and 8). Op. Cit.
[108] Mandrovsky, B. Soyuz–9. A manned biomedical mission. Op. Cit.
[109] Gurovskiy, N. N. et al. Some results of medical investigations carried out on the orbiting scientific laboratory. Op. Cit.
[110] Major medical aspects of the flight of the Soyuz–12 spacecraft. Op. Cit.
[111] Unsigned. Salyut 3 : Soviets still catching up. Christian Science Monitor, July 22, 1974, p. 1, 4.
[112] Soyuz–17/Salyut–4 : Daily routine and life support system. Op. Cit.

17 periods of relatively short lightness or darkness. The classical concept and perception of a 24 hour day, then, is lost in space. Moreover, the added stresses of weightlessness, confinement, background noises, and emotional tensions are superimposed upon this desynchronization. For these reasons, the interest of Soviet and American physiologists and space medicine specialists in daily physiological rhythms and the so-called "biological clocks" that drive them has increased markedly, particularly over the past five years.[113-115]

Soviet cosmonauts throughout the Soyuz/Salyut series of flights have adhered to a 24 hour duty cycle, which has included a 16 hour working day and 8 hours of sleep. This schedule has been based upon a large body of fundamental research carried out under conventional laboratory conditions as well as in unconventional environments such as Antarctica.[116] Soyuz/Salyut flights have generally been scheduled to conform to Moscow time or launch-site time. Some variations of the daily schedule have been tested, however, with displacements ranging from 3–9 hours. The rhythm of sleep and wakefulness during the Soyuz 3–8 flights was reported as relatively constant.[117] During the Soyuz 9 flight, however, there was a gradual shift in stages so that the daily cycle was shortened by an average of 30 minutes per day.[118] In general, Soviet cosmonauts have reported that less sleep is necessary during spaceflight than on Earth, so that flight sleep periods fall within the 6–7 hour range rather than the 7–8 hour range.[119] There is apparently less of a problem of a phase-shift in the work/rest cycle (desynchronosis) when it conforms closely to the natural diurnal rhythm of the cosmonaut.

Soviet research on biorhythms as related to spaceflight missions continues with emphasis on psychological and neurological factors involved in adaptation to new temporal situations. The belief persists that unfavorable responses to changes in work/rest cycles can be avoided by the formulation of optimum duty cycles which conform to the individual biorhythm of the cosmonaut and by preliminary adaptation of the cosmonaut to the new duty cycle prior to spaceflight. The static 24 hour cycle continues to be favored over phased variations in this cycle.[120] Some investigators have suggested that the interior of the spacecraft cabin be designed to simulate diurnal and seasonal variations conforming to the middle latitudes of the Soviet Union to facilitate adaptation to prolonged missions.[121] Recent Soviet research suggests that the process of adaptation to a new time zone or duty cycle requires about two weeks. The adaptation time can be decreased if the duty cycle is changed prior to exposure to a new situation and if the work load is increased.[122]

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[113] Brown, F. A., Jr. The "clocks" timing biological rhythms. American Scientist, Vol. 60, 1972, 756–765.

[114] Folk, G. E., Jr. Textbook of Environmental Physiology. Philadelphia. Lea and Febiger (2nd Ed.). 1974, p. 39–86.

[115] Leonov, A. A. et al. Psychological Features of Cosmonaut Activity. Op. Cit. p. 229–237.

[116] Medical Investigations During Arctic and Antarctic Expeditions. Vol. 229, Leningrad, 1971. 105 p. (JPRS 56225).

[117] Litsov, A. N. Rhythm of sleep and wakefulness in crews of the spaceships Soyuz 3–9 before, during, and after exposure to spaceflight. Izvestiya, Academy of Sciences, USSR (Biological Series). No. 6, 1972. 836–845 (JPRS 58173).

[118] Mandrovsky, B. N. Soyuz–9 flight, a manned biomedical mission. Op. Cit.

[119] Soyuz 17—Salyut 4: Daily routine and life support system. Op. Cit.

[120] Litsov, A. N. Some principles of developing work-rest cycles in prolonged manned spaceflights. Space Biology and Aerospace Medicine (USSR). No. 2. 1974. 71–75.

[121] Melaikov, L. N. Simulation of diurnal and seasonal rhythms in a spaceship interior. Space Biology and Medicine (USSR), No. 1. 1972, 74–77.

[122] Conference on Biorhythms. Nature (USSR), No. 2, 1975, p. 104 (Library of Congress. FRD #2359).

G. BIOMEDICAL FINDINGS

Although two Soviet space missions, Soyuz 1 (April, 1967) and Soyuz 11 (June, 1971) have terminated in the deaths of four cosmonauts, none of the fatalities were due to medical causes. If technical problems had not intervened (Tangled parachute shroud lines on Soyuz 1 and valve failure in Soyuz 11), it is probable that all of the cosmonauts would have returned in good health. Likewise, the remaining Soviet space missions of the Soyuz/Salyut series have been free of serious biomedical problems and all cosmonauts have returned to Earth in good condition with all medical indices within normal limits.

While both American and Soviet space missions have been free of major medical problems, minor ones continue to occur in both programs. As mentioned earlier, some Soviet cosmonauts have exhibited shifts in work/rest habits and have slept for shorter periods of time during space missions. In Soyuz 11/Salyut 1 mission this problem was corrected through the use of mild sedatives.[123-125]

Both American astronauts and Soviet cosmonauts have complained of a fullness or stuffiness of the head and chest, particularly during the initial phases of spaceflight. These uncomfortable, if not debilitating, sensations are apparently due to a shift in blood volume from the lower part of the body to the upper quadrant and head as a result of weightlessness. On Skylab 2, the astronaut-physician noted what appeared to be an engorgement of the jugular veins descending from the brain, which supports that explanation. These sensations are of a temporary nature and disappear after one or two days of spaceflight.[126-128]

Both American and Soviet space crews have occasionally experienced a temporary disruption of orthostatic tolerance after recovery. In the Soviet program, this condition was inexplicably most acute in the Soyuza 9 mission. Both cosmonauts complained of considerable difficulty in walking after the 18 day flight.[129] Temporary disturbances in coordination and orthostatic tolerance by using a stabilograph, a gimballed platform designed to test postural stability, were also noted in earlier Soviet flights.[130]

Decreased orthostatic tolerance and minor decreases in cardiac output have been noted in subsequent Soyuz/Salyut missions as determined by lower-body-negative-pressure (LBNP) tests. This test is apparently successful in detecting changes in cardiovascular condition in response to weightlessness. Apparently, exercise programs have been somewhat successful in minimizing these changes. [131, 132]

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[123] Gurovskiy, N. N. et al. Some results of medical investigations carried out during the flight of the scientific orbiting station, Salyut. Op. Cit.

[124] Litsov, A. N. Rhythm of sleep and wakefulness in crews of the spaceships Soyuz 3–9 before, during, and after exposure to spaceflight. Op. Cit.

[125] Parin, V. V. et al. Soviet research in space medicine. Op. Cit.

[126] Berry, C. A. The legacy of Apollo. Op. Cit.

[127] Dr. Kerwin's log of Skylab–1. Op. Cit.

[128] Mandrovsky, B. N. Soyuz–9, a manned biomedical mission. Op. Cit.

[129] Ibid.

[130] Purakhin, Yu. N. et al. Regulation of vertical posture after flight on Soyuz–6. Soyuz–8, and 120 day hypokinesia. Space Biology and Medicine (USSR), No. 6, 1972, 47–53 (JPRS 58070).

[131] Degtyarev, V. A. et al. Changes in indices of circulation in the crew of the orbital station, Salyut, during investigation in hypokinesia conditions. Space Biology and Aerospace Medicine (USSR), No. 2, 1974, 34–72.

[132] Degtyarev, V. A. et al. Results of examining the Salyut crew during the lower-body-negative-pressure test. Op. Cit.

Changes in plasma volume, certain blood components, blood chemistry, and certain metabolic indices are common to both Soviet and American crews. A decrease in total plasma volume and in certain blood components is apparently a compensatory reaction to the weightless state and is reversible upon return to Earth. Electrolyte balance and demineralization of bone tissue continues to be of concern to both programs. The latter condition in particular, involving a steady loss of calcium from bone tissue, is worrisome in terms of future, prolonged flights of several months duration.[133, 134]

Throughout the American Apollo/Skylab program and the Soviet Soyuz/Salyut program, some astronauts and cosmonauts have been stricken with transient episodes of motion sickness and nausea, a condition first experienced by Cosmonaut Titov on Vostok 2. These sensations have since been counteracted with drugs which suppress the parasympathetic nervous system such as plavephine and atropine in the Soviet program and a combination of scopolamine and dexadrine in the American program. The symptoms usually disappear after a day or slightly more of spaceflight. Apparently there is no completely reliable method of conditioning the vestibular systems of latently vulnerable astronauts or cosmonauts to prevent this uncomfortable condition, although exercises involving certain head movements conducted during the early phases of spaceflight are being tested and show some promise.[135, 136]

Finally, both American astronauts and Soviet cosmonauts have exhibited moderate losses of body weight as a result of spaceflight. Table 4–6 provides a sampling of cosmonaut weight loss in the Soyuz 4–12 series. Decreased body weight is not of a serious nature and is rapidly reversible upon return to Earth.[137,138]

TABLE 4–6.—DYNAMICS OF CHANGE IN BODY WEIGHT OF COSMONAUTS AFTER FLIGHT

Spacecraft	Flight duration (days)	Name of Cosmonaut	Change in body weight in comparison with original on day of launch (kg)			
			At place of landing	After flight (1 day)	Before water	After water intake
Soyuz–4	3	V. A. Shatalov	−3.9	−0.2	0	+0.2
Soyuz–5	3	B. V. Volynov	−2.4	−1.5	−0.1	+0.8
Soyuz–4, 5	2	Ye. V. Khrunov	−1.9	−0.7	−0.2	+0.5
Soyuz–4, 5	2	A. S. Yeliseyev	−2.0	−2.0	−1.5	+0.5
Soyuz–6	5	G. S. Shonin	−2.5	−1.5	−1.4	+0.1
Do	5	V. N. Kubasov	−2.1	−0.9	−0.7	+0.2
Soyuz–7	5	A. V. Filipchenko	−3.9	−2.1	−1.8	+0.3
Do	5	V. V. Gorbatko	−2.0	−0.8	−0.8	0
Do	5	V. N. Volkov	−2.4	−0.6	−1.3	−0.7
Soyuz–8	5	V. A. Shatalov	−2.2	+0.2	+0.2	0
Soyuz–8	5	A. S. Yeliseyev	−3.6	−1.6	−1.3	+0.3
Soyuz–9	18	A. G. Nikolayev	−2.7	−1.3	−1.3	0
Do	18	V. I. Sevast'yanov	−4.0	−2.3	−2.4	0
Soyuz–12	2	V. G Lazarev	−3.1	−1.9	−1.8	+0.1
Do	2.	O. G Makarov	−2.0	−0.9	−0.8	+0.1

SOURCE: Natochkin, Tu. V., Functional Tests in the Study of Water-Salt Exchange and Renal Function in Cosmonauts, 1973 (not published).

[133] Berry, C. A. The legacy of Apollo. Op. Cit.
[134] Legenkov, V. J. Variations in the composition of peripheral blood of cosmonauts during 18 and 24 day spaceflights. Op. Cit.
[135] Berry, C. A. The legacy of Apollo. Op. Cit.
[136] Bryanov, I. I. et al. Certain otorhinolaryngological problems in medical support of spaceflights. 1973, 12 p. (unpublished).
[137] Berry, C. A. The legacy of Apollo. Op. Cit.
[138] Natochin, Yu. V. Functional tests in the study of water-salt exchange and renal function in cosmonauts. 1973, 12 p. (unpublished).

In summary, the minor organic problems encountered by Soviet and American space crews have been amenable to medical intervention during space missions. As spacecraft have become larger, exercise equipment and medical/first aid supplies have increased the margin of biomedical safety so that orbital flights of up to 84 days have been successfully accomplished. The successful 63 day flight of Soyuz 18/Salyut 4 has further increased the Soviet confidence factor by yet another quantum. At present, there would appear to be no medical contraindications to flights of even longer duration.

IV. Life Support Systems and Technology

The life support system of a manned spacecraft is one of its most critical links, for any significant life support failure results in total mission failure. Therefore, the design of the life support system, which includes atmosphere, food and water, and waste disposal subsystems, is carefully predicated upon well developed empirical data on human energy requirements and waste generation. Thus, a 70 kilogram (144 pound) man aged 25–40 requires about 600 liters of oxygen, 600–800 grams of dry food, and 2.0–2.5 liters of drinking water per day. An additional 5–10 liters of water per day is required for personal hygiene and sanitation during prolonged spaceflights. At the same time, the human metabolism on a daily basis generates about 400–500 liters of carbon dioxide, 2.5–3.0 liters of water in the form of urine and perspiration, and 100–200 grams of solid waste. The life support system must be able not only to satisfy these basic challenges, but must do so on a sustained basis with virtually 100 percent reliability. It is therefore a tribute to bioengineers in both space programs that there has been no significant life support system failure on any of the 31 American or 26 Soviet manned spacecraft flown thus far.[139, 140]

A. Air Regeneration and Space Cabin Ecology

Since the very beginning of the manned spaceflight program, the Russians have used a physical-chemical system for the generation of oxygen and the removal of carbon dioxide. The American program, on the other hand, utilizes fuel cells as the source of oxygen and lithium hydroxide (LiOH) for carbon dioxide removal. The Soviet spacecraft atmosphere is maintained as close to the normal terrestrial value as possible (14.7 psi or 760 mm Hg barometric pressure; about 20 percent oxygen and 80 percent nitrogen), whereas the American spacecraft atmosphere is 100 percent oxygen at 5 psi (259 mm Hg) during the flight. Since the 1967 Apollo fire which occurred during a simulation test, a less flammable 60/40 oxygen/nitrogen mixture at 15 psi (776 mm Hg) is used during the launch phase. Upper and lower limits of cabin atmosphere parameters for Soviet manned spacecraft in the Soyuz/Salyut series are given below:[141-144]

Barometric Pressure (mm Hg): 710–900.
Oxygen Content (percent): 19–29.

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[139] Webb. P. Work, and Oxygen cost. In: Bioastronautics Data Book. Wash., D.C. NASA SP-3006. 1973 (2nd Ed.). p. 847–879.
[140] Rukavishnikov, N. N. et al. The Cosmonaut as Researcher, Op. Cit. p. 12.
[141] U.S. Library of Congress. Aerospace Technology Division. Foreign Science Bulletin, Vol. 3, No. 4. 1967, p. 7 (and other sources).
[142] Parin V. V. et al. Soviet research in space medicine. Op. Cit.
[143] Mandrovsky, B. Soyuz-9 flight, a manned biomedical mission. Op. Cit.
[144] Major medical aspects of the flight of the Soyuz-12 spacecraft. Op. Cit.

Oxygen Partial Pressure (mm Hg) : 164–199.
Carbon Dioxide Content (percent) : 0.1–0.6.
Carbon Dioxide Partial Pressure (mm Hg) : 3.0–8.5.
Relative Humidity (percent) : 35–80.
Air Temperature (degrees centigrade) : 13–30.

The chemicals preferred by the Russians for closed-system atmosphere regeneration, including the manned spacecraft series to date, are oxides and superoxides of the alkali metals. Table 4–7 provides the functional characteristics of a number of these chemicals which simultaneously release oxygen and absorb carbon dioxide. The chemical used for space cabin atmosphere maintenance is potassium superoxide (KO_2). This same chemical and others closely related to it are also used in undersea life support systems including diving gear. One astronaut requires about 4 kilograms of active chemical per day.[145-146]

TABLE 4–7.—OXYGEN CONTENT OF CERTAIN PEROXIDE COMPOUNDS OF ALKALI METALS AND THEIR CAPACITY FOR ABSORPTION OF CARBON DIOXIDE

Substance	Amount of active oxygen		Carbon dioxide absorption capacity, 1/kg
	%	1/kg	
Lithium peroxide Li_2O_2	31.7	242	487
Lithium superoxide LiO_2	61.5	430	287
Sodium peroxide Na_2O_3	20.5	143	287
Sodium superoxide NaO_2	43.6	305	203
Sodium ozonide Na_2O_3	56.3	394	158
Potassium peroxide K_2O_3	14.5	101.5	203
Potassium superoxide KO_3	33.8	236	158
Potassium ozonide KO_3	46.0	322	128.5

SOURCE: Umansky, S. P. Man in Space Orbit, Mashinostroyeniye Press, 1974, pp. 36–40.

A large variety of impurities are generated by man and his activities including carbon monoxide, ketones, alcohols, aldehydes, aliphatic acids, methane, unsaturated hydrocarbons, dust, bacteria, and viruses. These are removed from the Soviet spacecraft atmosphere by means of activated charcoal filters, dust precipitation filters, hopcalite and zeolite filters, special bacterial fibers, and chemical catalytic processes.[147]

Thermal regulation of the air is accomplished by air-liquid exchange. The cabin air is impelled by a fan through an air-liquid heat exchanger. The heated liquid is then pumped to an external heat exchanger and the heat is dissipated into space. The system is accurate to within ±1.5 degrees centigrade.[148]

Excess water generated by man in a closed system is about 50–60 grams per hour. Excess moisture in the space cabin atmosphere is removed by dehumidification. In Soviet manned spacecraft, a cooling drying technique is used to dehumidify the air. Air forced against a cool surface is condensed and the liquid phase is then removed using porous capillary wicks, ultimately passing into the water regeneration system.[149]

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[145] Shikanov, Ye. P. Handbook for Divers. Moscow. "Voyenizdat" Publishing House, 1972, p. 12–23 (JPRS 60691).
[146] Umanskiy, S. P. Man in Space Orbit. Moscow. "Mashinostroyenlye" Press, 1974, p. 36–40 (NASA TT–F–15973).
[147] Ibid.
[148] Girshavenkov, B. G. Air regenerating and conditioning. In: Foundations of Space Biology Vol. III. Part 1., 1975 (in press).
[149] Ibid.

The Russians have listed a number of attractive features of the active chemical air regeneration systems which explains their continued use not only in the manned space program but also in manned undersea programs. These features include efficiency of operation over a broad range of temperature, humidity, and barometric pressure; resistance to vibration, acceleration, heat, and explosion; simplicity of design; high operational reliability and automatic performance; and of major importance, relatively low system weight. The major Soviet misgiving about the use of stored or liquid oxygen systems is the comparatively high weight penalty as well as their vulnerability to disruption by a number of spaceflight factors. Hence, the Soviet use of active chemicals for spacecraft atmosphere control is expected to persist, at least through the Soyuz/Salyut series of spacecraft.[150]

B. WATER AND FOOD MANAGEMENT

Food supply and management on Soviet spacecraft was discussed under "Nutrition" in Section III. (Space Medicine). A more detailed account of this aspect of life support for both the American and Soviet spaceflight programs is provided by Popov.[151]

The stored-water management system on the earlier Vostok and Voskhod spacecraft consisted of a rigid metal container, an elastic container for water storage, a water supply line connected to a mouthpiece, a cartridge for disinfecting and deodorizing the water, and a water cutoff device. The water was consumed by sucking through the mouthpiece. A silver ion preparation (0.1–.14 milligrams per liter) was used for purification and mineralization. Some water was reclaimed from the dehumidifier.[152]

As spaceflight missions have increased in duration, more elaborate and efficient water management systems have become necessary. Water reclamation was first successfully tested in the Soviet year-long chamber experiment of the late 1960's and has since evolved into an operational system.[153] The water regeneration system aboard the latest Salyut 4 space station provides that moisture from respiration and perspiration can be reclaimed. Moisture is condensed in cooling and dehumidifier units and stored. The stored gas/liquid mixture is then fractionated, purified, decontaminated, and heated prior to human consumption. Minerals are added to the reclaimed water in solid form and include calcium, magnesium, bicarbonates, chlorides, and sulfates. A warning signal is flashed if impurities remain in the reclaimed water. Both stored and reclaimed water are used for human consumption in present Soviet spacecraft. Total consumption of water is about 2.2 to 2.5 liters per day per cosmonaut, including about 1.6–2.0 liters for drinking. During the 29-day Soyuz 17/Salyut 4 flight, the two cosmonauts consumed about 100 liters of water. The Soviets are now investigating more elaborate, closed water regeneration systems which would recycle virtually all water. Vaporization, sorbents, and semipermeable membranes are candidate approaches under consideration.

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[150] Umanskiy, S. P. Man in Space Orbit. Op. Cit.

[151] Popov, I. G. Food and Water Supply. In: Foundations of Space Biology and Medicine. Vol. III. Part 1., 1975 (in press).

[152] Ibid.

[153] Water and food regeneration in space. Pravda Ukrainy (USSR) Feb. 5, 1975, p. 2. (FRD #2234).

A major problem identified by Soviet scientists is the separation of gases from liquids in waste water.[154] [155]

C. WASTE MANAGEMENT AND PERSONAL HYGIENES

A grown man eliminates about 1.2 liters of liquid waste and 200 grams of solid waste per day. On early Soviet spacecraft of the Vostok and Voskhod series, these wastes were stored separately. The waste management unit consisted of a urine and solid waste receiver, air filter, and blower. Upon activation of the blower, there was a porous substance in the filter which deodorized the air before it was returned to the cabin atmosphere. Liquid wastes were stored in special tanks aboard the spacecraft while solid wastes were stored in plastic bags which were sealed and stored after use. Both solid and liquid wastes were treated with various chemicals to suppress decomposition. No doubt, the waste management systems on the more recent Soyuz/Salyut series are more elaborate, although they have yet to be described in detail. The Soviets continue to investigate various methods for treating, storing, and reclaiming water from human wastes including distillation at reduced pressure, wet combustion, electrolysis, and capillary devices used to separate gases from liquids in waste products.[156–158]

As the duration of space missions has increased, personal hygiene has become more vital as a link in the life support system and to the well being of the crew. Accordingly, on the Soyuz/Salyut missions, a variety of supplies and equipment has been provided for tooth and oral hygiene, cleaning of the body, face, and hands, shaving, washing clothes, and trimming the hair and nails. Vacuum cleaners have been provided for the collection of loose hair and other debris.[159, 160]

D. SPACE SUITS AND CLOTHING

The space suit is a portable life support system in which a microclimate suitable for human activity is maintained. In effect, the space suit is a miniature sealed cabin reduced to human dimensions. Air or oxygen in the space suit is used for pressurization in addition to respiration. Suits used for extra-vehicular activities in the Soviet manned spaceflight program are of two types. In the Vostok and Voskhod series of flights, space suit systems were of the open-circuit ventilation type whereby the expired air was vented into space. Pure oxygen was provided from tanks located in a back pack. In the Soyuz/Salyut series, regenerative space suits have been used in which the

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[154] Life support systems aboard the Soyuz-18-Salyut-4 flight. Izvestiya (USSR), June 7, 1975, p. 5 (FRD #2445).

[155] Salyut-4 water regeneration system. Pravada (USSR), May 31, 1975, p. 3. (FRD #2441).

[156] Yefimov, V. P. et al. Some methods for transporting liquid wastes of the vital functions of a crew and sanitary waste water during spaceflights. Space Biology and Medicine (USSR), No. 3, 1972, 24–28 (JPRS 56675).

[157] Umanskiy, S. P. Man in Space Orbit. Op. Cit.

[158] Borshchenko, V. V. Isolation and Elimination of Waste Products. In: Foundations of Space Biology and Medicine, Vol. III, Part 1. Ch. 5. Washington, D.C. NASA. 1975 (in press).

[159] Gurovskiy, N. N. et. al. Some results of medical investigations carried out during the flight of the scientific orbital station Salyut. Op. Cit.

[160] Finogenov, A. M. et al. Cosmonaut clothing and personal hygiene. In: Foundations of Space Biology and Medicine, Vol III. Part 1. Ch. 4. Washington, D.C. NASA. 1975 (in press).

expired air is recirculated through a carbon dioxide absorbent. The basic elements of space suits are a covering layer, detachable gloves, pressure helmet, and attached or detached (spacecraft) life support system. The outer layer provides structural strength and consists of a system of cables and cords. A layer of rubberized material covers the outer layer. Thermal insulation is provided by an elastic layer with low heat conductivity. Through the inner aspect of this layer, a ventilation system, powered by a centrifugal blower supplies respirable gas to various sections of the suit.[161-163]

Conventional clothing worn inside the pressurized spacecraft cabin is designed for comfort, hygienic properties, and durability. Underwear is made of cotton and rayon. Flight suits worn over the underwear are made of polyester fibers which possess high thermal protective capability, high durability, elasticity, and resistance to wrinkling, chemicals, bacteria, solar energy, and general wear. For short-duration spaceflights, Soviet cosmonauts wore clothing only once, after which it was discarded and stored. On longer-duration spaceflights of the Soyuz/Salyut series, flight clothing can be reworn after cleaning aboard the spacecraft. Soviet cosmonauts are also provided with conventional leather work boots of light weight.[164]

E. MAN-MACHINE INTERACTIONS

Unlike American spacecraft, in which the astronaut is the critical link in control and guidance, it has been continuing Soviet practice to minimize the role played by the cosmonaut in the spaceflight mission. Accordingly, the instrumentation inside the Soyuz cabin is minimally designed for human interaction. Cosmonauts have few if any launch duties. All command and control activities that are under cosmonaut control are carried out in the Soyuz descent module. The launch vehicle instrument panel contains no booster readouts or booster rocket guidance control. Nor do Soyuz crews have control over the timing of any necessary launch abort procedures which are carried out automatically or from the ground control station. During an abort, such as occurred in the recent Soyuz failure of April, 1975, the spacecraft shroud and descent module separation from orbital and service modules is under automatic control. Similarly, Soviet spacecraft orientation displays are virtually nonexistent and cosmonauts have no spacecraft attitude display or data on rates at which yaw, pitch, and roll maneuvers are made. Primary attitude reference is derived from the use of a simple periscope.[165]

The Soyuz spacecraft contains no man/machine interface typical of American spacecraft such as the Apollo digital computer which permits direct communication with the guidance and control systems. Virtually all Soviet operations are carried out by pre-programmed sequencers which cannot be manipulated either by the cosmonauts or

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161 Jones, W. Individual life support systems outside of a spacecraft cabin, space suits, and capsules. In: Foundations of Space Biology and Medicine, Vol. III. Part 1. Ch. 7. Washington, D.C. NASA. 1975 (in press).

162 Alekseyev, S. M. et al. Altitude and Space Suits. Moscow, "Mashinostroyeniye" Press, 1973, p. 198–219.

163 Umanskiy, S. P. Man in Space Orbit. Op. Cit.

164 Finogenov, A. M. et. al. Cosmonaut clothing and personal hygiene. Op. Cit.

165 Soyuz gives cosmonauts little control. Aviation Week and Space Technology, Jan. 21, 1974. 38–41.

ground crews. The sequencers are such that the Soyuz can be flown in the unmanned mode. Hand controllers do permit the cosmonaut to guide manually spacecraft attitude and translation. But in contrast, American spacecraft are provided with several control modes to guide spacecraft acceleration and rate.[166] Thus, the Soyuz is frequently referred to as a man-rated, unmanned spacecraft in which cosmonauts have minimal command, control, or trouble-shooting capability.

Aside from spacecraft manual control considerations, there is evidence that the Russians have devoted considerable thought and research to the general problem of space cabin habitability. They have also thoroughly reviewed American approaches to the problem. The result is a fairly empirical approach to the design of the spacecraft cabin and associated equipment. The Soyuz command module has been designed for utility and comfort. Instrument panels and consoles provide for the most efficient possible readout of data and manipulation by the operator. Other habitability factors of vital importance to crew function and well being are also being investigated in considerable depth. These include cosmonaut work-rest cycles and sociopsychology (discussed in Section II and III), illumination of spacecraft working and living areas, and space cabin housekeeping problems. These factors are assuming greater importance as the duration of space missions increases. Accordingly, Soviet research in this sphere is oriented toward interplanetary space missions of many months duration.[167]

F. RESCUE EQUIPMENT AND EMERGENCY MEASURES

As is the practice in the American manned space program, Soviet spacecraft are provided with emergency backup systems for virtually every link in the life support assembly. However, in the event of a catastrophic situation in which a space mission must be aborted, space crews are provided with emergency rescue equipment as well. In the Soyuz spacecraft, emergency separation of the descent module (which occurred in an April 5, 1975 Soyuz mission) is provided for during a launch phase malfunction by means of a solid fuel propulsion unit. Upon separation, the descent module parachute deploys for an eventual soft landing on either land or sea. Once landed, the crew is provided with a portable emergency supply unit in the event that landing has taken place in a remote area or far out at sea. The unit contains food, water, communications gear (radio with power source), clothing, fishing and hunting equipment, and medicine. In the early Vostok series, the portable emergency unit was contained in the cosmonaut's seat, which, with the cosmonaut in it, could be ejected from the space capsule during an abort or landing in a remote area.[168]

The portable emergency supplies aboard the Soyuz spacecraft are intended for two cosmonauts and are subdivided into four units: Insulated suits, flying boots and gloves are in the first and fourth units; foodstuffs with a total caloric value of about 4,500 calories (about a

[166] Ibid.

[167] Petrov, Yu. A. Physiological hygiene and psychological aspects of life organization in spacecraft cabins. In: Foundations of Space Biology and Medicine. Vol. III. Part 1. Ch. 6. Washington, D.C., NASA, 1975 (in press).

[168] Chernyakov, I. N. Protection of the life and health of crews of spacecraft and space stations in emergency situations. In: Foundations of Space Biology and Medicine. Vol. 3, Part 3, Chapter 14, Wash., D.C., NASA 1975, (In Press).

2–3 day supply), a medicine chest, radio station, signal flares, and knife are in the second unit; two suits for rescue at sea are contained in the third unit. The sea rescue suits are buoyant, insulated, and contain emergency supplies for prolonged immersion in cold water. In addition, a portable, automatically inflating life boat is also provided. Therefore, the Soyuz spacecraft appears to be adequately equipped with emergency gear for rescue on either land or sea.[169, 170]

Once in space, Soviet spacecraft are also provided with emergency equipment and procedures to be used in the event of sudden cabin depressurization, fire, or failure of the atmosphere control systems. In the event of sudden cabin depressurization, which occurred during the re-entry of Soyuz 11 in 1971, a number of life support resources have been developed or are being developed to supply emergency air and oxygen. These include full pressure suits, partial pressure suits, and pressurized compartments and capsules. Pressure suits have been available for emergency use in Soyuz spacecraft since the aforementioned accident. In the older Vostok series, the emergency air supply system was activated automatically when the cabin pressure dropped to 500–560 millimeters of mercury (normal pressure is about 760 millimeters of mercury). With a further drop in pressure to 400–460 millimeters of mercury, there was automatic delivery of oxygen and a signal was flashed for the cosmonaut to seal his pressure suit helmet. Of course, in that series of missions, the cosmonauts were already wearing the pressure suit, whereas in the Soyuz-Salyut series, the cosmonauts are dressed in conventional clothing. Table 4–8 describes the emergency rescue procedure in the event of sudden depressurization and illustrates how critical time is in such a situation.[171]

TABLE 4-8.—MEANS OF COSMONAUT PROTECTION AND RESCUE IN CASE OF RAPID DEPRESSURIZATION OF SPACECRAFT CABIN

Who performs rescue work	Available safety and rescue means	Available time for rescue work	Limiting factor	Terminology
The victim, independently.	LSS, full pressure suit, PPS.	10–15 sec	Time during which consciousness and fitness are intact.	"Reserve time," "time of useful consciousness."
Other crew members	LSS, full pressure suit, PPS, pressurized compartments.	120–150 sec	Time in which vital functions are retained.	"Total rescue time," "survival time."
Cosmonaut-physician	Same as above and resuscitation	150 sec. (up to 7 min. for animals).	Time of appearance of irreversible structural change.	"Resuscitation time."

SOURCE: Chernyakov, I. N., Protection of the life and health of the crews of spacecraft and space stations in emergency situations in Foundations of Space Biology and Medicine, Volume 3, Part 3, Chapter 13, Washington, D.C. NASA, 1975

In Soviet spacecraft, an atmosphere that is close in gas composition and pressure to that of the Earth is maintained during all phases of the flight, in contrast to American spacecraft which use a 100 percent oxygen atmosphere. With regard to fire safety, the Soviet practice is an advantageous one. But in the event of a spacecraft fire, a number of approaches are possible. The most direct one is to use the natural vacuum of space to extinguish the fire. This can be done by having the

[169] Umanskiy, S. P. Man in Space Orbit. Op. Cit.
[170] Volovich, V. G. Medical Aspects of the safe descent and landing of a spacecraft on earth and other celestial bodies. In : Foundations of Space Biology and Medicine. Vol. 3, Part 3, Chapter 13, Washington, D.C. NASA. 1975 (in press).
[171] Chernyakov, I. N. Protection of the life and health of the crews of spacecraft and space stations in emergency situations. Op. Cit.

crew dress in full pressure suits followed by complete or nearly complete depressurization of the space cabin. Another possible approach would be to saturate the cabin with an inert gas (preferably nitrogen in the Soviet case) with the crew wearing full pressure suits provided with an emergency oxygen supply.[172]

In the event of a failure in the air recycling and conditioning systems, Soviet spacecraft are provided with emergency backup systems as well as personal emergency gas supply systems in the form of full or partial pressure suits. The emergency systems are designed to prevent oxygen starvation (hypoxia), symptoms of too much or too little carbon dioxide (hypercapnea), and overheating while the main life support assembly is being repaired.[173]

G. FUTURE TRENDS AND SYSTEMS

Since the 1960's, both the Soviet Union and the United States have been developing prototype life support systems which will maintain small crews for a year or even longer. Unlike the expendable life support systems used thus far on lunar and orbiting spacecraft, life support systems for long duration flights of several months will be of the recycling or regenerative type. Such a closed or semi-closed circuit system, which would be used for mission durations measured in years, must provide the needed consumables, regenerate as many materials as possible, and eliminate all wastes. Such a life support system would perform four basic functions vital to the crew: Provide a safe and habitable breathing atmosphere, drinking water, food, and sanitation and hygiene. The atmosphere control system must regenerate breathable gases; regulate temperature and humidity; provide appropriate ventilation and extra breathing gases to compensate for inevitable gas leakage; monitor and control toxic gases in the atmosphere, and provide early warning signals in the event of unacceptably high levels of any toxic gaseous constituent; and finally, control particulates in the atmosphere including dust and microflora. Drinking water must be recycled from waste waters to conserve weight. Wherever feasible, pure water must be recycled even from human and biological wastes as well as housekeeping water. Above all, the recycling life support system must be virtually free of actual or potential malfunctions and must perform faultlessly virtually 100 percent of the time. The complexity of the closed-circuit life support system as shown in Figure 4–4 is therefore orders of magnitude greater than expendable (open-circuit) systems thus far developed.[174]

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[172] Ibid.
[173] Ibid.
[174] Jones, W. L. Life support systems for interplanetary spacecraft and space stations for long term use. In: Foundations of Space Biology and Medicine. Vol. III Part 2 Ch. 9, Washington, D.C. NASA, 1975 (in press).

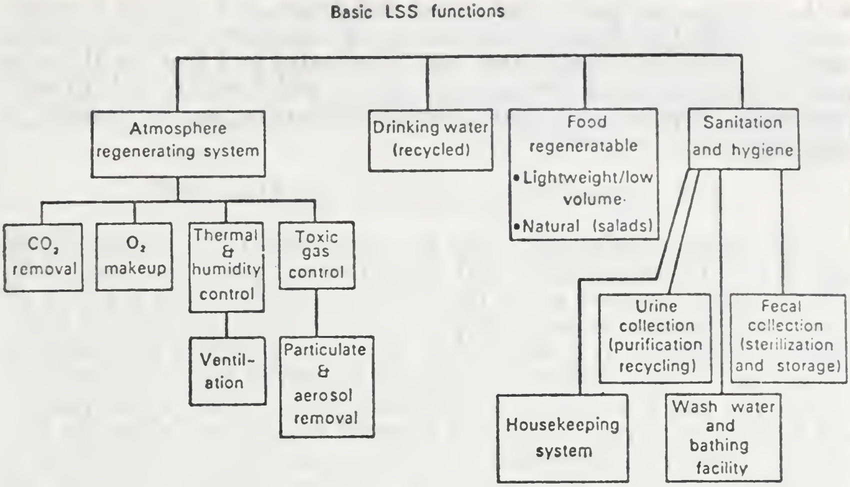

FIGURE 4-4.—Characteristics of integrated life-support systems

Source: Jones, W. L., Life support systems for interplanetary spacecraft and space stations for long term use. In Foundations of Space Biology and Medicine, Vol. III, Ch. 9. Wash., D.C., NASA. 1975 (in press).

The Russians have tested a number of prototype closed-circuit life support systems, the most notable one for a year long experiment involving three men in 1967. Both this test and a subsequent United States simulation of 90 days duration in 1970 demonstrated that life can be successfully sustained and that crewmen can perform efficiently for long periods of time in a system in which the basic components of life support are regenerated.[175]

More recent Soviet work with closed-circuit life support systems has concentrated on the concept of biological regeneration. To this end, the "Bios–3" complex was constructed to permit long-duration, man-rated tests involving different variants of biological life support systems. The complex is a welded block made of stainless steel divided into four equal compartments. The area of the block is 14 x 9 meters and the height is 2.5 meters. The compartments are linked by hermetic doors. Each compartment has an emergency exit. Two compartments contain higher plants, such as wheat and vegetables, one contains algae (Chlorella), and one is the crew living quarters. Simulated tests with 3 crew members have been conducted for durations of up to six months. No adverse changes in medical status of the crew have been noted and a high work capacity has been maintained.[176]

At the Institute of Biomedical Problems in Moscow, men have lived for up to 30 days in a hermetically sealed room in which oxygen was completely supplied by protococcal algae (Chlorella).[177] Extensive research is continuing with the goal of perfecting a 100 percent closed-circuit biological life support system consisting of algae, a variety of higher plants, and even bacteria which will not only provide the crew

[175] Ibid.
[176] Gitelson, I. I. et al. Life support system with internal control based on photosynthesis of high and unicellular plants. In: 24th IAF Congress, Krasnoyarsk, USSR, 1973, 34 p.
[177] Shepelev, Ye. Ya. Biological life support systems. In: Foundations of Space Biology and Medicine. Vol. 3, Part 2, Chapter 10, Washington, D.C., NASA. 1975 (in press).

with oxygen, and remove toxic gases and wastes, but provide nourishment as well. One is left with the strong impression that the Soviet effort in this field is very large and purposeful and that its ultimate goal is the creation of life support systems which will be able to support reliably crews in manned orbiting laboratories, and ultimately, in interplanetary spacecraft.[178, 179]

V. Gravitational Biology and Medicine

Since the very beginnings of the space programs of the United States and Soviet Union, aviation and space medical specialists have been particularly concerned about the influence of gravity or the lack of it on the organism. Accordingly, both countries have supported large research programs to investigate in detail the effects of accelerations (linear and radial), weightlessness, and terrestrial situations approximating the weightless state (water immersion, bed rest, hypodynamia and hypokinesia) on humans and animals. The concern about the biomedical effects of gravity can be better understood if the dynamics of a typical spaceflight are considered: During the launch phase, the space crew is exposed to brief but intense positive acceleration followed by prolonged exposure (thus far up to 84 days) to weightlessness. This long exposure to weightlessness is followed by yet another brief exposure to intense positive acceleration associated with the re-entry of the spacecraft through the dense layers of the atmosphere. Thus, in rather rapid sequence, a space crew is exposed to positive and negative extremes of gravity, having adapted for prolonged periods of time either to the Earth's gravity or to the weightlessness of space. Having somewhat adapted to weightlessness, the crew must finally re-adapt to the Earth's gravity. The transition from a positive to a null gravity situation is associated with alteration in human sensory perceptions, particularly those of the inner ear. Such an alteration often leads to vestibular disturbances. The Soviet space life sciences community therefore continues to investigate the effects of: 1) temporary and chronic linear accelerations; 2) temporary and chronic rotatory (Coriolis) accelerations; 3) impact accelerations; and 4) weightlessness. Under laboratory conditions, linear accelerations are simulated in centrifuges, while rotatory accelerations are simulated on rotating chairs, inside rotating drums, or in rotating rooms. Weightlessness is only poorly approximated on Earth by means of bed rest, bodily restriction, clinostats, or test stands which support human or animal subjects in planes other than vertical to the Earth's gravitational vector. Brief periods (a few minutes) of the true weightlessness can be produced by flying high performance aircraft through parabolic (Keplerian) trajectories.[180]

A. Linear Accelerations

Initially, there was considerable apprehension in the Soviet bioastronautics community that the health, and indeed the lives of cosmonauts would be imperiled by positive accelerations experienced during spacecraft launch and re-entry. Of particular concern to this day is the

[178] A Chlorella-based closed cycle life support system. Chemistry and Life (USSR), No. 5, 1974, 58–63 (FRD #2079).

[179] Research on closed cycle life support systems at the USSR Institute of Biomedical Problems. Pravda (USSR). April 2, 1975, p. 6 (FRD #2348).

[180] Smith, A. H. Principles of Gravitational Biology. In Foundations of Space Biology and Medicine. Vol. II, Ch. 4, Book 1. Washington, D.C., NASA, 1975, 129–162.

ability of cosmonauts to withstand brief exposures to re-entry accelerations following prolonged adaptation to weightlessness. Fortunately, these apprehensions have been somewhat exaggerated, for neither American nor Soviet crews to date have been seriously affected by any gravitational aspect associated with space missions. With respect to positive accelerations, engineering precautions such as antigravity suits, special harnesses, and contoured couches have precluded any deleterious physiological effects. As spacecraft have become larger, more powerful, and more sophisticated, the positive G-forces experienced by space crews have gradually decreased. As more aerodynamic spacecraft are developed, the problem of re-entry accelerations will diminish even more, so that positive acceleration will essentially cease to confront the bioastronautics community as a major problem. For these reasons, there has been a somewhat decreased emphasis on the part of American and Soviet research teams on the physiological effects of linear accelerations. Nonetheless, some research continues and Soviet researchers in particular are investigating the effects of centrifugal accelerations on the cardiovascular system, central nervous system, respiratory organs, major digestive organs, kidneys, endocrine glands, blood and blood-forming tissues, and metabolic processes. Although human tolerance of maximum accelerations has been fairly well determined, possible subtle alterations in various organs and tissues are not well known. In addition, there is an emphasis on determining the physiological effects of accelerations in combination with other physical factors such as altered gas atmospheres and radiation.[181-183] On a more theoretical level, the evolutionary aspects of gravitational perception is being investigated in considerable depth.[184-185]

In recent years, Soviet researchers have been concerned about the effects of accelerations on the cardiovascular system. Cardiovascular disorders resulting from gravitational influences are caused by a redistribution of blood mass in the body. The degree of redistribution and the accompanying changes in circulatory dynamics depend on the direction and force of the acceleration vector. The greatest cardiovascular changes are brought about by longitudinal ($\pm$Gz) accelerations while the least significant changes result from transverse ($\pm$Gx) accelerations. This is because the major blood vessels in the body are situated primarily along the longitudinal axis, hence blood is more vulnerable to displacement by a longitudinal acceleration vector. Methods of monitoring human performance are being developed in order to detect rapidly and predict the limits of human tolerance to various vectors and magnitudes of accelerations.[186-188]

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[181] Kotovskiy, Ye. F. et al. Functional morphology as a result of exposure to extreme factors. In Problems of Space Biology, Vol. 15, Moscow, "Nauka" Press, 1971, p. 5–180 (NASA TT–F–738).

[182] Chernigovskiy, V. N. (Ed.) Problems of Space Biology. Vol. 16. Moscow, "Nauka" Press, 1971. 335 p.

[183] Vasil'yev, P. V. et al. Prolonged linear and radial accelerations. In Foundations of Space Biology and Medicine. Vol. II, Ch. 5, Book 1. Washington, D.C., NASA, 1975, 162–213.

[184] Chernigovskiy, V. N. (Ed.) The gravitational receptor: evolution, structure, cytochemical and functional organization. In Problems of Space Biology. Vol. 12. Leningrad, "Nauka" Press, 1971, 523 p.

[185] Vinnikov, Ya. A. Evolution of the gravireceptor and its investigation under conditions of acceleration and weightlessness. Archives of Anatomy, Histology, and Embryology (USSR). No. 1, 1974, 10–25 (FRD #1703).

[186] Vasil'yev, P. V. et al. Prolonged linear and radial accelerations. Op. Cit.

[187] Shul'zhenko, E. B. Human tolerance of chest-spine accelerations. Space Biology and Medicine (USSR), No. 1, 1974, 84–85.

[188] Kotovskaya, A. R. Information value of pulse pooling in auricular vessels for the assessment of human tolerance to + Gz accelerations. Space Biology and Aerospace Medicine (USSR), No. 1, 1975, 59–66 (FRD #2290).

Intellectual and physical performance associated with brain circulation under the influence of accelerations has traditionally received considerable attention in the Soviet Union. Research continues to elucidate the mechanisms of changes in cerebral circulation and the effects of those changes on various functions such as vision, speech, and motor acts including spacecraft control functions. Methods of simultaneously monitoring a variety of physiological indices during accelerations such as the cardiovascular and nervous systems are being developed as tools for the selection of aviation and space personnel. The implication of these studies is that candidate fliers and cosmonauts will continue to be subjected to centrifuge runs during the selection and training process and that acceleration tolerance will continue to be used as an important index of physical fitness.[189–192]

Methods of increasing human resistance to the harmful effects of acceleration are being examined. Approaches to this problem include protective clothing, contoured couches, special harnesses, physical training, repeated exposure to centrifugal accelerations, and the use of pharmacological agents. The effects of various drugs on resistance to acceleration have been investigated. Suitable drugs would stimulate physiological compensatory mechanisms or depress the general activity of the body. Depressants such as chloral hydrate, sodium thiopental, and hexanal have been rejected because they disrupt cardiovascular activity, circadian rhythms and decrease tolerance of heavy activity. Trioxazine, a promising tranquilizer, has few undesirable side effects and has been successfully tested under experimental conditions. Stimulants of nervous system activity have also been tested and include caffeine, phenamine, corazol, and strychnine. Cardiovascular drugs tested include vasoconstrictors such as epinephrine and norepinephrine and vasodilators such as nitroglycerine and the cardiac glycosides. Another class of drugs includes those which normalize stress related to respiratory changes. Combinations of stimulants (centredin and securinin) have been found to reduce the adverse effects of accelerations. Many of these drugs are now routinely included in the Soyuz/Salyut medical kit for emergency use. Since the flight of Soyuz 9, after which the cosmonauts experienced difficulty in re-adapting to Earth's gravity, new, unspecified drugs have been added to enhance cardiovascular and muscular tonus and tolerance of acceleration. These drugs are also said to expedite re-adaptation to the Earth's gravity. However, the Soviets are cautious about the use of drugs under spaceflight conditions because various factors associated with the spaceflight tend to alter human response to pharmacological preparations. Therefore, only mild sedatives and aspirin-like preparations are believed to have been used on Soviet space missions completed to date.[193–195]

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[189] Zotova, N. I. Effect of body-to-head accelerations on telencephalon, vasculatore. Archives of Anatomy, Histology, and Embryology (USSR). No. 12, 1974, 37–43 (FRD #2409).

[190] Zubavin, V. B. et al. Application of multichannel rheography for physiological studies on a centrifuge. Space Biology and Medicine (USSR). No. 5, 1972, 75–79 (FRD #1020).

[191] Nikonov, A. V. et al. Influence of prolonged accelerations on the structure of speech signals. Military Medical Journal (USSR), No. 9, 1973, 50–53 (FRD #1359).

[192] Zorile, V. I. et al. Action of prolonged longitudinal accelerations on the habit of steering. Military Medical Journal (USSR), No. 6, 1972, 89–94 (FRD #999).

[193] Vasil'yev, P. V. et al. Pharmacological substances and resistance of the organism to accelerations. In Problems of Space Biology. Vol 17. Moscow, "Nauka" Press, 1971, 83–172 (FRD #826).

[194] Vasil'yev, P. V. et al. Effect of psychotropic substanres on man's tolerance to accelerations. Space Biology and Medicine (USSR), No. 3, 1972, 50–59.

[195] Medical Gazette (USSR) July 18, 1975, p. 3.

The possibly negative effect on acceleration tolerance of other protective drugs such as radioprotective agents is also of concern to Soviet researchers. They are apprehensive that factors such as weightlessness, acceleration, ionizing radiation, and artificial gas atmospheres may alter normal human response to drugs. Some experiments have indicated that certain aminothiol and indolylalkylamine radioprotectors markedly alter animal responses to and tolerance of accelerations. Thus along with the benefits conferred by various protective drugs, there is also a risk factor which must be evaluated before protective drugs can be administered under actual spaceflight factors.[196]

Ongoing Soviet research on the effects of acceleration is concentrating on cellular and cytogenetic investigations of human beings and animals in order to elucidate the mechanisms of acceleration effects. Thus far, no cytogenetic changes have been detected in the somatic cells of humans subjected to accelerations of 4–10 G. The effects of accelerations on cerebral circulation will be continued and refined in order to develop techniques for better predicting brain tolerance of this factor. Information will continue to be developed on permissible limits for human beings relative to work capacity. The beneficial effects of oxygen and other gas mixtures will also be evaluated. Data on human resistance to transverse (Gx) accelerations will continue to be gathered as well as data on the physiological effects of accelerations in combination with other factors. Finally, methods of protection against the adverse effects of linear accelerations will continue to be developed.[197, 198]

B. WEIGHTLESSNESS AND SIMULATED WEIGHTLESSNESS

Of continuing concern to Soviet and United States aerospace biomedical researchers are the various effects of weightlessness on the human body. At the very beginning of the manned spaceflight era, there were serious doubts as to whether man and animals could survive in a gravity-free state for even a few hours. The earliest Soviet biosatellite flights using dogs, mice, and other organisms provided encouraging evidence that this was probably not so. After the Vostok flights, there was cautious optimism that man could survive for at least a few days in zero gravity. But the 18 day flight of Soyuz 9 temporarily re-kindled doubts about the seriousness of weightlessness effects, because both cosmonauts experienced considerable difficulty (orthostatic intolerance) in readapting to Earth's gravity. As it developed, this was an anomaly, because subsequent Soviet and American spaceflights of up to 63 and 84 days in duration respectively have been a success in the medical sense that space crews have been minimally affected by weightlessness.[199-200]

Many problems of a biomedical nature associated with weightlessness remain which will demand continuing research into the origin, prevention, and treatment if spaceflights of many months or years in duration are to be realized. The most significant of these problems are

[196] Antipov, V. V. et al. Study of the reactivity of the organism exposed to transverse accelerations. Aerospace Medicine, No. 8, 1971, 837–839.
[197] Bobkova, N. N. Results of cytogenetic investigations of the effects of 4–10 G accelerations on humans. Space Biology and Aerospace Medicine (USSR), No. 6, 1974, 77–78.
[198] Vasil'yev, P. V. et al. Prolonged linear and radial accelerations. Op. Cit.
[199] Berry, C. The legacy of Apollo. Op. Cit.
[200] Parin, V. V. et al. Weightlessness (Biomedical Research). Moscow, "Meditsina" Publishing House, 1974, 456 p. (FRD #2097).

changes in orthostatic and vestibular tolerance; increased susceptibility to disease and infection; altered reactivity to drugs; decreased tolerance of acceleration and physical activity; demineralization of bones; various changes in blood circulation; kidney function; respiration; metabolism; and general deconditionng. The various reactions to weightlessness as they are now known have been summarized from the literature by Pestov et al. as shown in Tables 4–9 [201]

[201] Pestov, I. D. et al. Weightlessness. In: Foundations of Space Biology and Medicine. Vol. II, Ch. 8, Book 1. Washington, D.C., NASA, 1975, 305–354.

TABLE 4-9—REACTIONS OF MAN AND ANIMALS TO EFFECTS OF WEIGHTLESSNESS

Reactions 1	Conditions and objects of observations [1] 2	Notes
Sensations of an unsupported position, floating, falling, spinning, turning, flow of blood to head, deterioration of orientation in space, predominance of visual information role in evaluating position of body in space	Man (TW, KP, SF)	Emotional coloring of sensations (fear, joy, etc.) depends on experience and training of subjects; in orbital flight-adaptation
Displacement of successive visual image during G-forces—downward (oculogravic illusion), and upward during weightlessness (oculoagravic illusion): illusions are characteristic of initial periods in weightlessness	Man (KP, SF)	Actual position of visual targets during G-forces—above the successive image, and below it during weightlessness; with gaze fixed on a target, the successive image coincides with it
Slowing down of speed and accuracy of movements; errors in trying to hit center of target (deviation of hits upward)	Man (KP, SF)	Only in initial phase of SF, then adaptation
Deterioration of ability to carry out measured muscular efforts and evaluate differences in mass of objects not fastened down	Man (KP)	
Pulse frequency: slowing of normalization following action of G-forces; subsequent tendency toward slowing, increase in variability (possible arrhythmias of the bigeminal type); in final stage of long SF, slight increase	Man, animals (SF)	With PBR following initial decrease in frequency of pulse, increase in frequency (lack of training)
Arterial pressure: moderate decrease, followed by stabilization, tendency toward decrease in pulse pressure	Man (SF)	In PBR, initial decrease followed by increase (sympathetic effect)
Heart: decrease in size (according to data from x-ray studies); symptoms of decrease in the contractile ability (according to electrocardiographic and seismocardiographic data and results of phase analysis of cardiac cycle)	Man (SF, R)	Descriptions of cases of increased mechanical activity of heart during flight
Bone tissue: demineralization (according to the data from x-ray photometry) due to loss of Ca	Man, animals (R)	No changes observed when using method of photon absorption
Muscles: decrease in volume and strength	Man, animals (SF, R)	Primarily atrophy of antigravitational musculature
Dehydration (decrease in plasma volume, followed by loss of intracellular fluid)	Man, animals (R)	Decrease in plasma volume develops on 1st or 2nd (Henry-Gauer reflex); recovery possible later
Decrease in weight (mass) of the body by 2–5% of original value	Man, animals (R)	Stay on moon in individual cases decreased body weight loss; following flight, weight rapidly returned to normal (exception; 18-d flight of Soyuz-9)
Protein metabolism: increase in blood urea content; increased excretion of creatinine with urine, negative nitrogen balance	Man, animals (SF, R)	Similar changes in PBR
Lipid metabolism; increase in the cholesterol, lecithin, and nonesterfied fatty acid content of blood	Man, animals (SF, R)	Changes not constant, depending also on nature of diet
Decrease in excretion of Na-, Cl-, K- electrolytes with urine	Man, animals (R)	Related to previous losses of electrolytes during weightlessness
Reduced excretion of 17-oxycorticosteroids, in flight increase in excretion following flight	Man (SF, R)	Similar relationship in experiments with simulation of weightlessness
Increase in concentration of antidiuretic hormone, aldosterone, and renin	Man (R)	Increase in aldosterone also noticed in SF
Blood: neutrophilic leukocytosis lymphopenia, or lymphocytosis, eosinopenia, increase in ROE[?], changes in coagulatory and anti-coagulatory systems of blood; thrombocytes—decrease or absence of changes	Man, animals (SF, R)	Similar changes in experiments with PBR
Delay in excretion of water from organism in test with waterload	Man (R)	Not noticed after 18-d flight of Soyuz-9
Deterioration of tolerance o transverse G-forces during launch	Man (SF)	Not on all flights

TABLE 4-9—REACTIONS OF MAN AND ANIMALS TO EFFECTS OF WEIGHTLESSNESS—Continued

Reactions	Conditions and objects of observations [1]	Notes
1	2	
Sensation of heaviness of body, rapid fatigue, difficulty in walking, muscular pains	Man (R)	Primarily after long-duration flights without preventive measures
Changes in postural, oculomotor reflexes and behavior	Animals (TW, KP)	Changes less in delabyrinthized animals than in normals
Decrease in oculomotor activity, asymmetry of nystagmoid movements	Man (SF)	
Development of pain during movement or individual symptoms of it (dizziness, discomfort in stomach, nausea, vomiting)	Man (KP, SF)	Participation of both vestibular and extralabyrinthic mechanisms suggested, as well as change in interaction of afferent systems
Frequency of respiration and pulmonary ventilation: increase during flight along the KP: various changes in SF: increase in post-flight period	Man (KP, SF, R)	Changes in flight depend on previous action of G-forces or nature of the work
Gas exchange: increase during flight along a KP: decrease (according to data from analysis of regenerative substance) during the SF: increase during post-flight period	Man (KP, SF, R)	Based on an analysis of samples of expired air, collected during the SF, both a decrease and an increase were noted: decrease in the PBR
Decrease in food consumption	MAN (SF)	Not observed on all flights: characteristic of PBR
Orthostatic instability	Man (R)	Develops also under conditions of terrestrial experiments involving simulation of weightlessness
Decrease in physical working capacity	Man (R)	Consequence of hypodynamia
Decreased immunity	Man, animals (R)	Increased danger of infectious diseases during and after flight
Increase in recovery period on long compared with short flights	Man (R)	Improved living conditions and preventive measures shorten recovery period

[1] TW—tower of weightlessness; KP—Keplerian parabola; SF—space flight; R—readaptation period; PBR—prolonged bed rest

SOURCE: Berry (1973) as cited by Pestov, I D et al. Weightlessness In Foundations of Space Biology and Medicine, vol. II, Ch. 8, Wash., D.C., NASA, 1975, pp. 305–354.

A number of hypotheses about the various mechanisms and pathways of weightlessness effects have been presented as have theories about processes of adaptation to this factor. These are also summarized by Pestov et al. below (Figures 4–5, 4–6, and 4–7) : [202]

[202] Ibid.

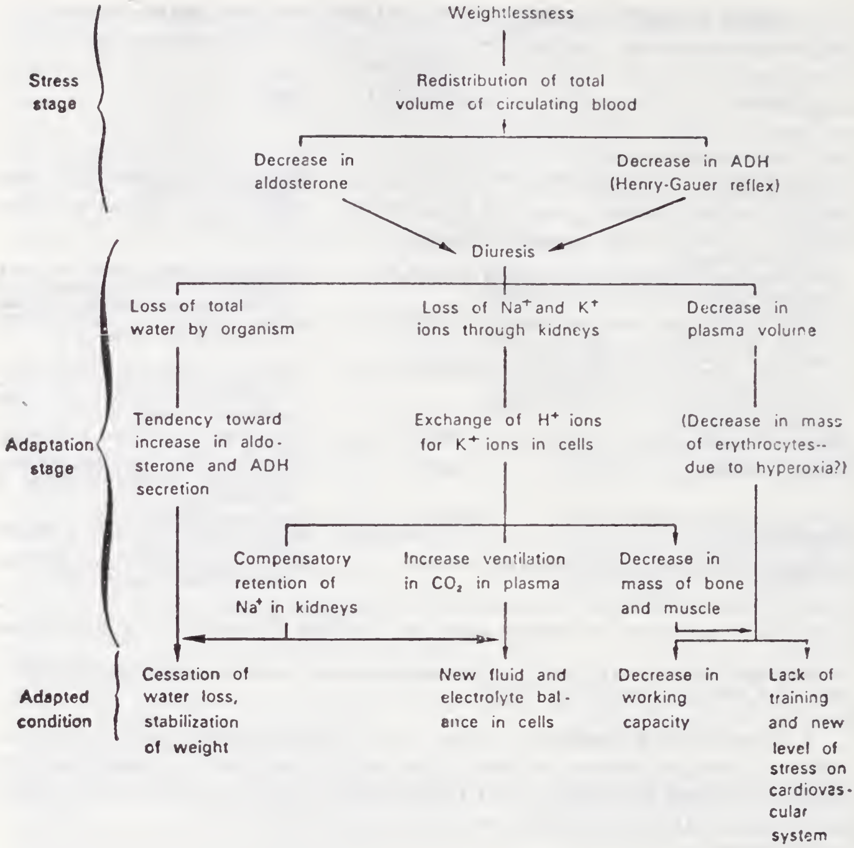

FIGURE 4–5.—Proposed process of adaptation to weightlessness.

Source: Leach (1970) as cited by Pestov, I. D. et al. Weightlessness. In: Foundations of Space Biology and Medicine. vol. II, ch. 8, Washington, D.C. NASA, 1975. pp. 305–354.

Event	Response of body
Entry into zero gravity; redistribution of circulating blood volume	Body attempts to reduce volume: ADH decreases, aldosterone production decreases
Loss of water, sodium, potassium (loss of body weight)	Decrease in plasma volume; aldosterone increases (secondary aldosteronism)
Increased sodium retention: potassium loss continues: cell: acidotic—extracellular fluid: alkalotic	Intracellular exchange of potassium and hydrogen ions; decrease in bone density, muscle cell potassium, and muscle mass—possibly including cardiac muscle
Respiratory and renal compensation; halt to weight loss trend	Stabilizes with new effective circulating blood volume; new body fluid and electrolyte balance or "set"

FIGURE 4–6.—Overview of Current Hypothesis Concerning Processes Involved in Man's Adaptation to Zero Gravity

Source: Berry (1971) as cited by Pestov, I. D. et al. Weightlessness. In: Foundations of Space Biology and Medicine, vol. II, ch. 8, Washington, D.C., NASA, 1975. pp. 305–354.

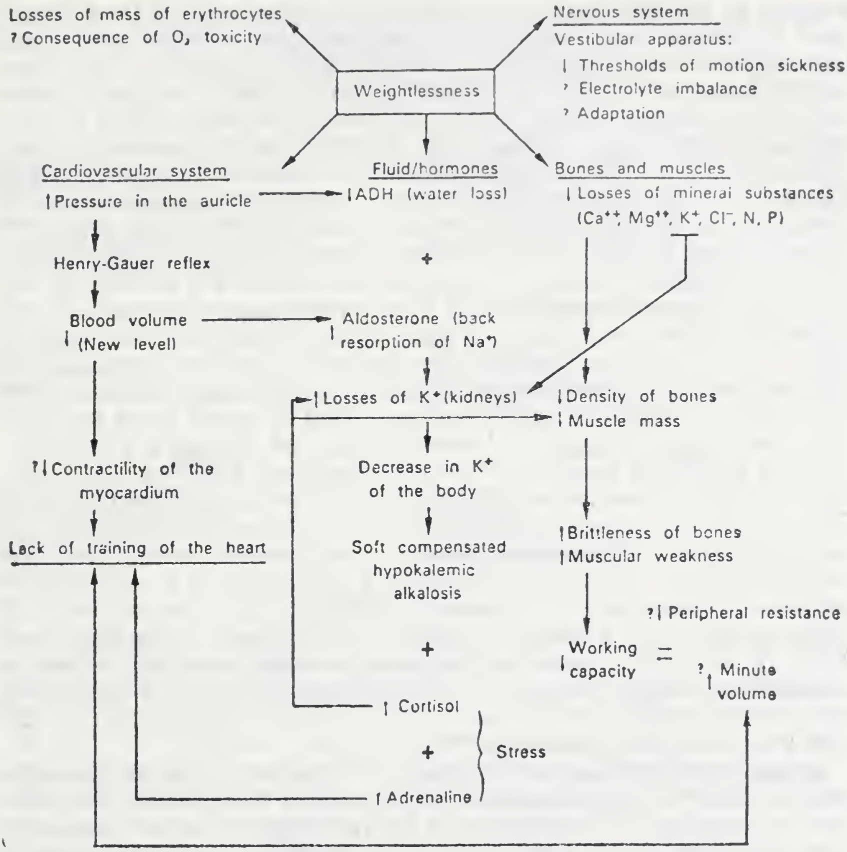

FIGURE 4–7.—Effects of the Influence of Weightlessness on Man (Working Hypothesis).

Source: White (1972) as cited by Pestov, I. D., et al, Weightlessness. In: Foundations of Space Biology and Medicine. Vol. II, ch. 8 Washington, D.C. NASA 1975, 305–354.

One additional subject of particular interest to Soviet researchers is the influence of weightlessness on the dynamics of cerebral circulation. One reason for this concern is persistent reports by cosmonauts and astronauts of a feeling of full-headedness or stuffiness during initial phases of adaptation to zero gravity. Another reason for concern is that any persistent changes in cerebral circulation carry with them the potential danger that mental performance might be negatively influenced. Therefore, methods are being developed to detect changes in cerebral circulation under actual spaceflight conditions and to pinpoint mechanisms of changes in the dynamics of circulation under a variety of physical conditions.[203]

Considerable research is being conducted to develop methods for predicting the influence of prolonged exposure to weightlessness. Since spaceflights are an extremely expensive method of experimentation, it is necessary to generally approximate conditions of weight-

[203] Moskalenko, Yu. Ye. Intracranial Blood Circulation Under Spaceflight Conditions. Moscow, 'Meditsina" Publishing House, 1971, 278 p. (FRD # 1208).

lessness in the laboratory. A number of approaches have been developed by Soviet and United States researchers including prolonged hypodynamia and hypokinesia, bed-rest, water immersion, and prolonged isolation in spacecraft mockup and specially designed chambers. Short term exposure to true weightlessness can only be accomplished by flying high performance aircraft through parabolic trajectories. The aim of Soviet experiments is to determine and predict the limits of human tolerance to simulated spaceflight conditions and to develop methods for enhancing human tolerance of these conditions.[204] As mentioned in Section IV of this chapter, Soviet isolation experiments in specially designed chambers have lasted for as long as one year with minimal degradation of human performance or medical conditions. The first year-long test with three subjects was conducted in 1967.[205] A second year long test has reportedly just been completed.[206] Bed rest and hypokinesia experiments involving many subjects of up to 120 days in duration have been conducted in recent years to elucidate mechanisms of physical deconditioning and changes in physiological and metabolic processes.[207, 208] Even hypnosis has been used to induce a subjective sensation of weightlessness in Soviet experiments.[209] Of considerable interest to Soviet researchers is human tolerance of acceleration after prolonged exposure to conditions approximating the weightless state. The general finding is that there is a considerable decrease in acceleration tolerance particularly after experiments of 30 or more days.[210] Another concern is altered reactivity to drugs and shifts in work-sleep patterns which occurs after prolonged exposure to simulated weightlessness.[211-213] Finally, cardiovascular changes and cerebral hemodynamics are of concern after prolonged (up to 120 days) exposure to hypokinesia.[214 215]

A number of approaches are being developed to counteract the deleterious effects of weightlessness. One approach would avoid the problem of adapting to weightlessness by rotating the entire spacecraft around its own axis to produce artificial gravity. The other approach, presently receiving the most attention, would involve physical conditioning and the use of drugs and special garments to minimize the effects of the weightless environment. Both concepts are summarized below (Table 4–10) :[216]

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[204] Kopanev, V. I. et al. Physiology of the sensory sphere of man under spaceflight conditions. In: Foundations of Space Biology and Medicine. Vol. II., Ch. 15, Book 2. Washington, D.C., NASA, 1975, 571–560.

[205] Smirnov, K. M. Hypokinesia. Successes of the Physiological Sciences (USSR), No. 1. 1972, 3–20 (FRD #918).

[206] Aviation Week and Space Technology. March 10, 1975, p. 11.

[207] Portugalov, V. V. et al. Morphological and cytochemical studies of hypokinetic effects. Aerospace Medicine, No. 10, 1971, 1041–1049.

[208] Murakhovskiy, K. I. et al. Mineralization of human bone tissue in conditions of water immersion. Space Biology and Medicine (USSR), No. 6, 1973, 72–75 (FRD #1502).

[209] Weightlessness under hypnosis. Socialist Industry (USSR), Nov. 18, 1973, p. 4.

[210] Barer, A. S. Man's tolerance of accelerations after prolonged exposure to conditions simulating weightlessness. Space Biology and Medicine (USSR), No. 3, 1972, 49–53.

[211] Kas'yan, I. I. External respiration, gas metabolism and energy expenditure in the case of varying human activity under conditions of weightlessness. Izvestiya of the Academy of Sciences, USSR. Biological Series. No. 5, 1971, 673–681 (JPRS 54493).

[212] Belay, V. E. et al. Influence of 30 day hypokinesia on the reactivity of the organism to pharmacological preparations. Space Biology and Aerospace Medicine (USSR), No. 4, 1974, 83–84.

[213] Artishchuk, V. N. et al. Influence of 30 day bed rest on dynamics of higher nervous activity and sleep of operators. Space Biology and Aerospace Medicine (USSR), No. 5, 1974, 75–79.

[214] Moskalenko, Yu. Ye. Intracranial Blood Circulation Under Spaceflight Conditions. Op. Cit.

[215] Tizul, A. Ya. et al. Cerebral hemodynamics during 120-day clinostatic hypokinesia. Space Biology and Medicine (USSR) No. 4, 1972, 72–77.

[216] Pestov, I. D. Weightlessness. Op. Cit.

TABLE 4–10.—MEANS OF PREVENTING ADVERSE EFFECTS OF LONG-TERM WEIGHTLESSNESS

Partial adaptation to weightless state	
Physical exercise	**Acceleration**
Calisthenics	On-board centrifuge
All kinds of sports	Trampoline
Tumbling, diving, zero-G training	Oscillating support
Isometric & isotonic contractions	Vibrating bed
Bicycle and hand ergometers	Space station rotation
Head movements during zero-G	
Controlled environment	**Drugs and medication**
Hypoxia	Aldosterone
Low temperature	Antidiuretic hormone
Diets	Plasma expanders
	9α-fluorohydrocortisone
Pressure	**Counteractives**
Pressure breathing	Glucose
Positive pressure cuffs	Pitressin
Elastic garments	Anabolic hormones
Lower body negative pressure	Electrostimulation
Anti-G suit	

Complete adaptation

Preconditioning of organism to subgravity level or zero-G state: reconditioning organism to force of normal terrestrial gravitation.

Source: Pestov, I. D. et al. Weightlessness. In: Foundations of Space Biology and Medicine. Vol. II. Ch. 8. Washington, D.C., NASA, 1975, pp. 305–354.

Among the problems associated with the first approach are the sheer expense and size of the hardware required, the different magnitudes of acceleration which would occur in a large rotating system, supply and control programs, and the little-known physiological effects of a constantly rotating system. Many Soviet specialists therefore continue to favor the second approach since it provides for partial adaptation to weightlessness while at the same time allowing for measures to prevent the major unfavorable consequences of such adaptation. The manned spaceflight record to date has thus far vindicated the second approach.[217 218]

The use of lower body negative pressure (LBNP) as a method of conditioning the cardiovascular system against weightlessness continues to be practiced on Soviet spaceflights and investigated under laboratory conditions. In experiments, LBNP selectively applied during prolonged immobilization and bed rest, increases orthostatic tolerance and cardiovascular tonus. LBNP is also a useful tool for detecting signs of de-adaptation brought on by prolonged exposure to actual or simulated weightlessness. The use of lower body over-pressure (LBOP) in combination with other measures is also being investigated as a means of preventing deconditioning.[219-222]

[217] Ibid.
[218] Genin, A. et al. Measures against the unfavorable effect of weightlessness. Aviation and Cosmonautics (USSR), No. 3, 1972, 30–33 (JPRS 55714).
[219] Pestov, I. D. Appraisal of the prophylactic effect of LBNP during a 30 day bed-rest regimen. Space Biology and Aerospace Medicine (USSR) No. 4, 1974, 51–55 (FRD #1956).
[220] Aleksandrov, A. N. Effect of 30 day bed rest and LBNP on the functional state of the cardiovascular system at rest. Space Biology and Aerospace Medicine (USSR), No. 1, 1974, 71–72.
[221] Suvorov, P. M. et al. Study of the possibility of using LBNP in the diagnostics of susceptibility to syncopes. Space Biology and Aerospace Medicine (USSR), No. 3, 1974, 53–56.
[222] Asyamalov, B. F. et al. Substantiation of LBOP needed to prevent orthostatic disturbances. Space Biology and Medicine (USSR), No. 6, 1973, 56–60 (FRD #1499).

Physical exercise, antigravity garments, and electrical stimulation of select muscle groups continue to be investigated individually or in combination with other conditioning approaches, including LBNP, to counteract the deconditioning effects of weightlessness. Electrical stimulation of muscles has shown promise in experiments and has been tested under spaceflight conditions. Experiments suggest that a higher degree of effectiveness is achieved when deeply located muscles are strongly stimulated. Physical exercise regimens using a variety of training devices, including stretch garments, springs, and expanders appear to have had successful results during spaceflights of up to 62 days duration in the Soviet program.[223-225]

Pharmacological countermeasures against weightlessness effects are also being investigated, despite the often-stated apprehension that human reactivity to drugs is altered during exposure to this factor. Such preparations as caffeine, phenamine, and securinin are now included in the Soviet spacecraft drug kit, although none of these drugs are believed to have been used thus far in any spaceflight.[226]

In summary, it has been found that Soviet and American space crews have been able to adapt to long periods (63 and 84 days) of weightlessness and have experienced few difficulties upon return to the Earth's gravity. Physical and equipment approaches to the problem of counteracting the unfavorable effects of weightlessness have worked quite well, so that it is believed that orbital flights in present-generation space stations of 90–120 days are feasible. Flights of even longer duration are somewhat more worrisome, at least to Soviet specialists, and speculation persists that some sort of artificial gravity may be necessary for flights of many months or years in duration. Future spacecraft are therefore envisioned which will be very much larger than present generation space stations. These would be constructed in orbit module-by-module to form large rotating complexes capable of accommodating large numbers of personnel.[227-228]

C. ROTATORY ENVIRONMENTS AND VESTIBULAR FACTORS

The vestibular organ is the major receptor of acceleration which relays information to the brain. It consists of fluid-filled semi-circular canals, the otolithic apparatus, connecting neurons, and cortical centers. Under weightless or rotatory conditions, the otoliths, small grain-like structures in a capsule, lose weight or are shifted directionally. These changes have a variety of effects on the human organism ranging from unpleasant to dangerous. In general, vestibular disorders are expressed as sensations of disorientation and nausea which can occur when the body is rotated rapidly or when it is exposed to zero gravity.

Vestibular dysfunction has been a persistent concern, first in the Soviet manned spaceflight effort and later in the American program.

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[223] Barer, A. S. Physiological and hygienic substantiation of the design of individual measures to prevent the adverse effect of weightlessness. Space Biology and Aerospace Medicine (USSR). No. 1, 1975, 41–47.

[224] Gornago, V. A. et al. Use of an anti-gravity suit in persons with decreased orthostatic tolerance. Space Biology and Aerospace Medicine (USSR), No. 5, 1974, 73–75 (FRD #2047).

[225] Katkovskiy, B. S. Human physiological performance after 30-day hypokinesia during which prophylactic measures were used. Space Biology and Aerospace Medicine, (USSR), No. 4, 1974, 43–47 (FRD #1954).

[226] Vasil'yev, P. V. et al. Pharmacological agents and weightlessness. Basic responses of the organism to the effect of prolonged hypodynamia and weightlessness. In: Problems of Space Biology, Vol. 17. Moscow, "Nauka" Press, 1971, 173–197 (FRD #827).

[227] Rukavishnikov, N. Artificial gravity aboard spacecraft. Aviation and Cosmonautics (USSR). No. 6, 1974, 40–41 (FRD #1892).

[228] Unsigned. Izvestiya (USSR), July 23, 1974, p. 5 (FRD #1945).

As mentioned earlier, the Soviet cosmonaut, Titov, first experienced dizziness and nausea during the flight of Vostok 2. Later, other Soviet and American space crews were to experience similar symptoms. Soviet cosmonauts have reported that illusions of vestibular origin are intensified during rapid head movements and are analagous to sensations experienced during rotation. Some American astronauts have developed weak signs of motion sickness which did not seriously affect work capacity. Four Soviet cosmonauts have reported moderate vestibular disturbances. Of 27 Apollo astronauts, 6 have reported unpleasant sensations in the stomach, two have reported nausea and vomiting, and three have reported spatial disorientation and illusions. While none of these episodes has been of an incapacitating nature, the phenomenon is of sufficient concern to justify a considerable research effort in both space programs to elucidate the mechanisms of vestibular disorders while developing approaches to prevent or treat them.[229-230]

Motion sickness is a major side effect of the weightless and rotating environments although the genesis of the disorder differs in each environment. There is a heavy investment of Soviet and American research effort to determine the mechanisms by which vestibular disturbances occur under a variety of situations. In both programs, rotating chairs, counter-rotating striped drums, and entire rotating rooms in which test subjects can remain for days and weeks are used. The Soviet literature on the subject of vestibular function is extensive. The research effort is devoted to both theory and practice with particular emphasis on the physiology and anatomy of the vestibular apparatus; the relationship of the vestibular apparatus to the brain and other sensory systems; the response of the vestibular apparatus to various rotatory and Coriolis accelerations; the genesis and prevention of motion sickness; the vestibular training of fliers and cosmonauts; and vestibular pharmacology.[231-234] What emerges from these studies is the fact that human head and body movements relative to the plane of rotation as well as repeated exposure and training play an important role in the onset, severity, and duration of vestibular autonomic reactions. There is also considerable interaction between the vestibular apparatus and other sensory systems, most notably the visual analyzer.[235-238]

There is a close relationship between vestibular stability and neurohumoral function. For example, high tolerance of rotatory accelerations is associated with increased epinephrine and norepinephrinese-

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[229] Yuganov, Ye. M. et al. Physiology of the sensory sphere under spaceflight conditions. In: Foundations of Space Biology and Medicine, Vol. II, Ch. 15, Book 2. Washington, D.C., NASA, 1975, 571–599.

[230] Graybiel, A. Angular velocities, angular accelerations, and coriolis accelerations. In: Foundations of Space Biology and Medicine, Vol. II, Ch. 7, Book I. Washington, D.C., NASA, 1975, 247–304.

[231] Bryanov, I. I. et al. The genesis of vestibulo-automatic disorders in spaceflights. Space Biology and Aerospace Medicine, (USSR) No. 3, 1975, 85–88.

[232] Bryanov, I. I. Certain otorhinolaryngological problems in the medical support of spaceflights. Op. Cit.

[233] Kalinovskaya, I. Vestibulomotor Reactions in Man. Moscow, "Mir" Publishing House, 1970, 165 p. (Translated by M. Singer).

[234] Khilov, K. L. Function of the Organ of Equilibrium and Motion Sickness. Leningrad, "Meditsina" Publishing House, 1969, 278 p.

[235] Solodovnik, F. A. Tolerance of rotation with continuous and intermittent head movements. Military Medical Journal (USSR), No. 4, 1974, 53–55 (FRD #1818).

[236] Polyakov, B .I. Peculiarities of the nystagmic reaction of human beings after their exposure to linear accelerations. Space Biology and Aerospace Medicine (USSR), No. 3, 1974, 60–63.

[237] Kekhayev, V. N. Interrelationship between the vestibular and visual analyzers. Herald of Otorhinolaryngology (USSR), No. 13, 1974, 54–57 (FRD #1904).

[238] Kurashvili, A. E. et al. Problems of interaction of the vestibular and optic analyzers. Space Biology and Aerospace Medicine (USSR), No. 2, 1974, 42–47.

cretion while low tolerance is associated with decreased secretion of these substances.[239]

Other physical factors such as heat and gas atmosphere play a role in the sensitivity of the vestibular analyzer to rotatory accelerations. High temperature, particularly in the 45–50°C range, decreases human resistance to motion sickness. Similarly, a hypoxic gas mixture (10.5 percent oxygen and 89.5 percent nitrogen) increases vestibular sensitivity while decreasing vestibular stability. On the other hand, an atmosphere rich in oxygen (40–43 percent) and carbon dioxide (2 percent) increases vestibular stability to rotatory stimuli.[240-242]

As a result of the large body of theoretically oriented research, a number of approaches are being developed to detect space crew candidates with latent or subtle vestibular sensitivity to spaceflight factors. At the same time, methods are being developed to train cosmonauts in order to prevent, or at least delay and minimize anticipated vestibular disorders during spaceflight. For example, a series of 2,622 experiments were conducted between 1961 and 1970 on 777 subjects. The subjects were exposed to pressure and heat chambers, spacecraft mockups, and aircraft which flew through parabolic trajectories to produce short term weightlessness. They were also exposed to rotating chairs and other vestibular training devices. The results of these tests were compared with data from the Vostok and Soyuz flights. It was determined that isolation, decreased atmospheric pressure, a helium-oxygen atmosphere, hypokinesia, overheating, and hypoxia significantly decreased vestibular and orthostatic tolerance. All kinds of physical activity were found to improve tolerance. Figure skating, water sports, basketball, and soccer were the most effective approaches, while running was the least effective. A crawl swimming stroke with simultaneous rotation and rotational chair training with fast head movements were two particularly effective exercises. The most effective methods of determining vestibular sensitivity in pilots and cosmonauts were tolerance tests in aircraft and the use of a vestibular test with simultaneous optokinetic stimulation.[243-245] Recently, the selective tensing of shoulder muscles has been found to decrease the severity of motion sickness and to shorten the subsequent recovery period.[246]

As with other spaceflight stresses, the Soviets have conducted considerable research on pharmacological preparations which prevent or suppress motion sickness and vestibular disorders. A novel preparation tested in 1972 was sodium hydrocarbonate. Intravenously injected, the preparation was tested in the laboratory, in clinics, and at sea. A

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[239] Nemchenko, N. S. Effect of Coriolis acceleration accumulation on catecholamine excretion. Military Medical Journal (USSR), No. 4, 1974, 55–56 (FRD #1822).

[240] Yuganov, E. M. et al. Influence of high temperature on the onset of motion sickness. Military Medical Journal (USSR), No. 6, 1972, 86–88.

[241] Sidelnikov, I. A. et al. Threshold sensitivity of the vestibular analyzer during hypoxia. Space Biology and Aerospace Medicine (USSR), No. 6, 1974, 55–58.

[242] Markaryan, S. S. et al. Effect of increased oxygen and carbon dioxide content on vestibular resistance. Space Biology and Aerospace Medicine (USSR), No. 2, 1975, 65–68.

[243] Khilov, K. L. Certain problems of vestibular function evaluation in pilots and cosmonauts. Space Biology and Aerospace Medicine (USSR), No. 5, 1974, 476–498 (FRD #1965).

[244] Kopanev, V. I. The problem of human statokinetic tolerance in aviation and space medicine. Izvestiya of the Academy of Sciences, USSR. Biological Series. No. 4, 1974, 476–498 (FRD #1965).

[245] Yakovleva, I. Ya. et al. Function of spatial coordinate perception during active, passive, and complex vestibular training. Space Biology and Aerospace Medicine (USSR), No. 5, 1974, 60–66 (FRD #2040).

[246] Ayzikov, G. S. et al. Human tolerance of Coriolis accelerations while tensing various groups of muscles. Space Biology and Aerospace Medicine (USSR), No. 3, 1975, 69–74 (FRD #2480).

positive effect was noted a few days after injection which persisted for several months. The mechanism of action of this preparation is obscure and its present status as a motion sickness drug is not known.[247]

A whole plethora of more conventional drugs to counteract motion sickness have been tested. Most have been anticholinergics, antihistamines, and tranquilizers used individually or in combination. Prophylactic vitaminization with pyridoxine containing compounds has also been tested with favorable results. The drugs included in the Soyuz/Salyut medical kit for vestibular disorders and motion sickness include plavefin, atropine, ethaperazine, and trioxazine. Apparently, plavefin is the most commonly used drug for motion sickness. It is not known whether these drugs have actually been used during space missions.[248-251]

Because there has been considerable speculation in recent years that future Soviet orbiting space stations will be of the rotating type, vestibular physiologists are concerned about the chronic effects of large-system rotation on the orientation and vestibular well-being of future crews. The magnitude of the effect of Coriolis acceleration will depend on the rotational velocity of the spacecraft, the angular velocity of head movements by the crew, and the angle between the axes of rotation of the spacecraft and a crew member's head. The vestibular effects of chronic (up to one month) rotation in large rotating chambers are therefore being investigated in considerable detail with large numbers of test subjects. Experiments suggest that, in order to reduce the effects of rotation on the vestibular apparatus, crew members will need to move their head translationally. The experiments also indicate that chronic rotation increases vestibular tolerance of that factor which persists for up to two weeks after exposure. If rotating space stations become a reality in the future, space crews may find themselves undergoing lengthy training in large rotating rooms prior to space missions.[252 253]

D. NOISE AND VIBRATION

In recent years there has been relatively little space-related literature on the physiological and psychological effects of noise and vibration. Most of the extensive literature on these subjects appears in the field of occupational hygiene. This may indicate that Soviet spacecraft design has reached a stage where neither of these two factors are as much of a biomedical threat as they were considered to be in earlier phases of the Soviet space program.

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[247] Barnatskiy, V. N. et al. Use of sodium hydrocarbonate as a means of treating and preventing motion sickness. Space Biology and Medicine (USSR), No. 6, 1972, 70–75.

[248] Vasil 'yev, P. V. et al. Vestibular function disturbance and medicinal prophylaxis of motion sickness. In: Problems of Space Biology. Vol. 17. Moscow, "Nauka" Publishing House, 1971, 198–230

[249] Lapayev, P. V. et al. Prophylactic vitaminization with pyridoxine-containing compounds as a means of preventing vestibular disturbances. Hygiene and Sanitation (USSR), No.5, 1971, 30–34 (JPRS 54048)

[250] Gurovskiy, N. N. et al. Some results of medical investigations carried out during the flight of the orbiting scientific station. Salyut. Op. Cit.

[251] Motion sickness. Medical Gazette (USSR), May 24, 1974, p.3 (FDR # 1859)

[252] Solodovnik, F. A. et al. Effect of Coriolis acceleration on the vestibular apparatus of a cosmonaut and its experimental study in the laboratory. In: Problems of Bionics. Moscow. "Nauka" Press, 1973, 53–58 (FRD # 1353).

[253] Galle, R. R. et al. Certain principles of adaptation to prolonged rotation. Space Biology and Aerospace Medicine (USSR), No. 5, 1974, 53–60 (FRD # 2044).

Of some concern to Soviet space medicine specialists are the chronic effects of relatively low intensity, high frequency noise of the type encountered in spacecraft cabins emanating from life support units and other systems. For example, Soviet experiments have indicated that exposure of human subjects for 30 days to high frequency noise with an intensity of 74–76 decibels (85–90 decibels is generally considered to be the threshold for hearing damage) will lead to a sensation of the ears being stopped up. Recovery from this sensation requires about 40 hours. Exposure of subjects for 60 days to 60–65 decibel high frequency noise resulted in an insignificant decrease in auditory sensitivity. Therefore, it may be assumed that prolonged high frequency noise levels in Soviet spacecraft do not exceed 65 decibels and are probably well below that level. The Soviets consider changes in auditory thresholds to be a good index of psychophysiological reactions to other factors such as hypodynamia and isolation.[254]

Vibrations are also of concern, although they have not apparently presented any great problem to space crews thus far. It has been found that vibrations are better tolerated in a standing rather than in a sitting or semirecumbent position typical of space-crews. Exposure to vertical vibration causes changes in higher nervous activity expressed as apathy and somnolence. Subsequent changes in vibration, tactile, and pain sensitivity may occur along with disorders of the visual and vestibular systems. Subjects chronically exposed to vibration may become neurotic and suffer serious deterioration in vision. Decreased visual acuity is directly related to the amplitude and frequency of vibration. A 40 percent decrease in visual acuity has been noted at a vibration frequency of 20 cycles per second and an amplitude of 1.6 millimeters. Such severe vibrations apparently have not been encountered on Soviet spacecraft.[255] [256]

VI. Problems of Space Radiation

A. The Space Radiation Environment

The duration of a spaceflight, its trajectory, and various other parameters determine the type of exposure to space radiations and the corresponding radiation hazard to the crew. The three types of radiation encountered in space include primary cosmic or galactic radiations, solar radiation, and geomagnetically trapped radiations in the Van Allen belts which surround the Earth.[257]

Primary cosmic radiations are made up of protons (about 85 percent), alpha particles (about 12 percent) and heavy nuclei (about 2 percent). The activity of cosmic radiation events is fairly constant so that throughout the solar system there is relatively little difference in radiation intensity. Near Earth, cosmic radiation intensity varies in 11 year cycles.[258]

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[254] Yuganov, Ye. M. Physiology of the sensory sphere under spaceflight conditions. Op. Cit.

[255] Ibid.

[256] Notes on the Second Symposium, "Influence of Vibration on the Human Organism and the Problem of Vibration Protection." Space Biology and Aerospace Medicine (USSR), No. 6, 1974, 82–83.

[257] Parker, J. F. et al. (Ed.) Bioastronautics Data Book. Op. Cit. pp. 417–454

[258] Ibid.

Solar activity also varies in 11 year cycles. At the peak of solar activity, giant eruptions on the surface of the sun, termed solar flares, occur. These develop rapidly and last from 30 to 50 minutes during which time intense radiation is emitted. The intensity of radiation varies substantially with the size and activity of a solar flare. High energy protons, alpha particles, and a few heavy nuclei emitted during solar flare activity constitute a radiation hazard to spacecrews outside of the Van Allen belts of geomagnetically trapped radiation.[259]

There are two belts of geomagnetically trapped radiation around the Earth which contain electrons and protons. Space vehicles with trajectories of 30 degrees inclination from the equator or larger will traverse these Van Allen belts five times each day. Nearly the entire accumulated radiation exposure of all orbital missions to date is attributable to Van Allen belt radiation. But the dose received by spacecrews has been determined to be of no biologically significant hazard.[260 261]

The characteristics of space radiations are summarized in Table 4–11.

TABLE 4–11.—NATURE AND LOCATION OF ELECTROMAGNETIC AND PARTICULATE IONIZING RADIATIONS IN SPACE

Name	Nature of Radiation	Charge	Mass	Where Found
Photon	Electromagnetic	0	0	Radiation belts, solar radiation (produced by nuclear reactions and by stopping electrons), and everywhere in space
X-ray	Electromagnetic	0		
Gamma ray	Electromagnetic	0	0	
Electron	Particle	−e	1 m_e[1]	Radiation belt and elsewhere
Positron	Particle	+e	1 m_e	Cosmic rays, radiation belt, solar flares
Proton	Particle	+e	1,840 m_e or 1 amu[2]	Primary cosmic rays, radiation belt, solar flares
Neutron	Particle	0	1,841 m_e	Secondary particles produced by nuclear interactions involving primary particle flux
Pi meson	Particle	+, −, or 0	273 m_e	Cosmic rays, radiation belt, solar flares
Alpha particle	Particle	+2e	4 amu	Primary cosmic radiation (nucleus of helium atom)
Heavy primary nuclei	Particle	+3e	6 amu	Primary cosmic radiation (nuclei of heavie atoms)

[1] m_e=electron mass.
[2] amu=atom mass unit
(Newell & Naugle, 1960; Sondhaus & Evans, 1969; Glasstone, 1958)

SOURCES: The Bioastronautics Data Book, 1974.

In addition to the above, there is a fourth type or secondary type of radiation which occurs after primary radiation has passed through a resistant substance such as the spacecraft structure or radiation shielding. This type of radiation is often referred to as bremsstrahlung and consists of gamma rays.

The radiation doses accumulated by Soviet and American astronauts during space missions are summarized in Table 4–12.

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[259] Ibid.
[260] Ibid.
[261] English, R. A. Apollo experience report: protection against radiation. Washington, D.C., NASA. 1973. 15 p. (NASA TN-D-7080)

TABLE 4-12.—AVERAGE DOSE ABSORBED BY THE ASTRONAUTS, ACCORDING TO THERMOLUMINESCENT DOSIMETRY DATA

Spaceship [1]	Av. absorbed dose (mrad)	Spacecraft [1]	Av. absorbed dose (mrad)
Vostok	2.0	Gemini 3	23.0
Vostok 2	11.0	Gemini 4	46.0
Vostok 3	62.0	Gemini 5	176.0
Vostok 4	45.0	Gemini 6	25.0
Vostok 5	80.0	Gemini 7	164.0
Vostok 6	44.0	Gemini 8	10.0
		Gemini 9	19.0
Voskhod	30.0	Gemini 10	720.0
Voskhod 2	60.0	Gemini 11	28.0
		Gemini 12	20.0
Soyuz 3	85.0		
Soyuz 4	70.0	Apollo 7	156.0
Soyuz 5	62.0	Apollo 8	150.0
Soyuz 6	70.5	Apollo 9	202.0
Soyuz 7	63.0	Apollo 10	468.0
Soyuz 8	72.5	Apollo 11	173.0
Soyuz 9	323.5	Apollo 12	577.0
		Apollo 13	237.0
Salyut	870.0	Apollo 14	1142.0
		Apollo 15	300.0
		Apollo 16	500.0
		Apollo 17	600.0
		Skylab	2500–3500

[1] Inclination of orbit for Vostok and Voskhod spaceships=65°; for Soyuz ships=52°; for Gemini craft=33°; for Apollo craft=31–33°; for Skylab, 50°.

SOURCE: Tobias, C. et al. Ionizing Radiation. In: Foundations of Space Biology and Medicine, Vol. II, Ch. 12, Wash. D.C., NASA, 1975, pp. 473–531.

During the first occupation of Salyut 4, the average 24-hour dosage was about 15–20 millirads.

Despite a higher orbit, the radiation dose was relatively small as a result of low solar activity.[262-263]

The more significant radiation effects which could occur in the event of harmful radiation doses include:

Early Effects:
- Skin erythema and desquamation.
- Gastrointestinal and neuromuscular effects.
- Depression of blood formation.
- Decreased fertility or sterility.
- Early death.

Late Effects:
- Permanent or delayed skin changes.
- Increased incidence of cataract.
- Increased incidence of leukemia and other cancers.
- General shortening of life span.[264]

In the Soviet Union, the dose standards for short term spaceflights of up to 30 days, expressed in rem (roentgen equivalent man; roughly equivalent to rad), have been calculated as:

Allowable dose—15 rem.
Dose of justified risk—50 rem.
Critical dose—125 rem.

As can be seen in Table 4–10, the radiation doses thus far absorbed by astronauts and cosmonauts have not even approached the allowable dose level. Nonetheless, there continues to be concern in Soviet and American bioastronautics circles that solar flare events could expose

[262] Tobias, C. et al. Ionizing radiation. In Foundations of Space Biology and Medicine. Vol. II, Ch. 12, Book 2. Washington, D. C., NASA, 1975, pp. 473–531
[263] Trud. (USSR) Feb. 1. 1975. p. 2
[264] Langham, W. H. Radiobiological factors in space conquest. Aerospace Medicine, No. 8, 1969, 834–843

space crews to doses exceeding the allowable level, particularly during prolonged interplanetary flights. Soviet estimates of the maximum allowable dose of radiation for such flights have been calculated as follows:

Flight Duration (years):	*Maximum Allowable Dose (rem)*
1	200
2	250
3	275

It should be noted that there is considerable variation in recommended maximum allowable radiation doses for prolonged flights in the international bioastronautics community. Some experts have recommended that space crews could receive a dose of 300 rem per year of flight.[265]

B. BIOMEDICAL ASPECTS OF SPACE RADIATION

Since the recognition of potential hazards from space radiation, the Soviet Union has supported an extremely large effort to determine systematically and empirically what effects the various types of ionizin radiation have on man, animals, plants, and micro-organisms and how to prevent or minimize these effects. The basic philosophy behind this large research effort is that radiation injury has no threshold. Therefore, any exposure to ionizing radiation, regardless of dose, can be potentially harmful. Moreover, radiation has a cumulative effect on biological systems which means that even a relatively small radiation doses can be damaging if exposure time is prolonged.[266–269]

A large data base has been accumulated by Soviet and American researchers on the clinical effects of whole-body radiation. These effects at acute radiation dose levels are summarized in Table 4–13.

TABLE 4–13.—EXPECTED SHORT-TERM EFFECTS FROM ACUTE WHOLE-BODY RADIATION

Dose in Rads	*Probable Effect*
10–50	No obvious effect, except, probably, minor blood changes.
50–100	Vomiting and nausea for about 1 day in 5%–10% of exposed personnel. Fatigue, but no serious disability. Transient reduction in lymphocytes and neutrophils.
100–200	Vomiting and nausea for about 1 day, followed by other symptoms of radiation sickness in about 25%–50% of personnel. No deaths anticipated. A reduction of approximately 50% in lymphocytes and neutrophils will occur.
200–350	Vomiting and nausea in nearly all personnel on first day, followed by other symptons of radiation sickness, e.g., loss of appetite, diarrhea, minor hemorrhage. About 20% deaths within 2–6 weeks after exposure; survivors convalescent for about 3 months, although many have second wave of symptoms at about 3 weeks. Up to 75% reduction in all circulating blood elements.

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265 Tobias, C. Ionizing Radiation. Op. Cit.
266 Ibid.
267 Kuzin, R. A. Radiation Barrier in the Road To Space. Moscow, "Atomizdat" Publishing House, 1971, 134 p.
268 Gurovskiy, N. N. The Function of the Organism and Factors of Spaceflight. Moscow, "Meditsina" Publishing House, 1974, 232 p. (FRD # 2078)
269 Generozov, V. L. Establishment of methods for calculating the radiation hazard of protons from solar flares. Space Biology and Aerospace Medicine, No. 13, 1975, 74–76.

850–550	Vomiting and nausea in most personnel on first day, followed by other symptons of radiation sickness, e.g., fever, hemorrhage, diarrhea, emaciation. About 50% deaths within 1 month; survivors convalescent for about 6 months.
550–750	Vomiting and nausea, or at least nausea, in all personnel within 4 hours from exposure, followed by severe symptoms of radiation sickness, as above. Up to 100% deaths; few survivors convalescent for about 6 months.
1000	Vomiting and nausea in all personnel within 1–2 hours. All dead within days.
5000	Incapacitation almost immediately (minutes to hours). All personnel will be fatalities within 1 week.

Source: (Langham, 1967) as cited in The Bioastronautics Data Book, 1974.

Less perfectly understood are the delayed effects of low levels of ionizing radiation at dose levels of less than 5 rem. Therefore, extensive research continues to be conducted to determine the effects of protons, heavy ions, and other types of corpuscular space radiations on man, animals, plants, and micro-organisms at the macroscopic and microscopic level.[270]

Soviet scientists continue to concentrate on investigations of the effects of ionizing radiations at the organ level. Of particular interest are effects on critical organs and organ systems such as the eye, vestibular apparatus, central nervous system, blood, and metabolic and immune processes.[271] Light flashes experienced in space by cosmonauts and astronauts are theorized by some researchers to be an indication that the retina is extremely sensitive to penetrating cosmic radiations and high energy particles.[272 273]

There is also considerable interest in the long-term effects of cumulative doses of low-level ionizing on the incidence of tumors, genetics, and the general longevity of animals, plants, and micro-organisms. Soviet experiments on dogs chronically exposed to low levels of radiation for up to four years have been conducted with periodic and systematic examinations of various organs, tissues, and those of the progeny of irradiated dogs. Those studies reflect Soviet interest in the radiobiological aspects of very long-duration spaceflights.[274 275]

Recently there has been heavier Soviet emphasis on cytological, biochemical, genetic, and molecular mechanisms of ionizing radiation effects. Specimens ranging from human tissue cultures to the most primitive micro-organisms are being surveyed in order to elucidate the mechanisms of radiation sensitivity and resistance. By better understanding these mechanisms it is anticipated that methods of protecting organisms, including man, from the adverse effects of radiations can be developed.[276–278]

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[270] Tobias, C. et al. Ionizing radiation. Op. Cit.
[271] Ibid.
[272] Demirchogliyan, G. G. Visual effects of the eye-penetrating cosmic rays and high energy particles. Biophysics (USSR), No.2, 1974, 314–318 (FRD # 1785)
[273] Grigor'yev, Yu. G. et al. Optic effects of cosmic rays. Space Biology and Aerospace Medicine (USSR), No.4, 1975, 46–53
[274] Shilov, V. V. et al. Natural immunity of dogs exposed to long-term chronic gamma irradiation. Space Biology and Medicine (USSR), No. 5, 1973, 23–28.
[275] Yakovleva, V. I. Development of tumors in dogs chronically exposed to low doses of gamma radiation. Space Biology and Aerospace Medicine, No. 6, 1974. 20–24.
[276] Ivanov, V. I. Radiobiology and genetics of Arabidopsis. In: Problems of Space Biology. Vol. 27. Moscow, "Nauka" Publishing House, 1974. 191 p. (FRD # 2023)
[277] Grigor'yev, Yu. G. et al. Cytological and cytogenetic effects in bacterial and mammalian cells due to the action of accelerated heavy ions. Space Biology and Aerospace Medicine (USSR), No.2. 1974, 308
[278] Kuzin, A. M. Effect of Ionizing Radiations on Cell Membranes. Moscow, "Atomizdat" Publishing House, 1973, 112 p. (FRD # 1589).

While most research on space radiobiology is conducted on Earth, a great many experiments have been conducted on biological satellites and manned spacecraft to obtain first hand data on the various effects of space radiations. Table 3–5 of Chapter Three (p. 233) summarizes manned and unmanned spaceflights in which biological experiments, primarily of a radiobiological character, have been conducted. Some of these experiments have indicated that spaceflight factors (primarily radiation and weightlessness) can affect cell genetics and reproduction. An abnormally high number of chromosomal changes have been observed in some insect larvae. Spaceflight factors have increased the germinating capacity of a variety of plant seeds. These findings are of interest because the Russians are particularly interested in the use of higher plants as critical links in future spacecraft life support systems. However, it remains a matter of conjecture as to whether space radiation can increase the incidence of genetic changes in human or animal cells, since many of these experiments have yielded data of inconclusive or borderline significance. For this reason, it is expected that the Russians will continue to develop methods for better evaluating the effects of space radiations.[279]

C. RADIATION IN COMBINATION WITH OTHER SPACEFLIGHT FACTORS

While it is more expedient, less complicated, and certainly less expensive to study the isolated effects of individual spaceflight factors on the organism, such an approach is not entirely realistic in the view of many Soviet bioastronautics specialists. For many spaceflight stresses rarely act on the body individually, but as complex influences. In other words, the space crew is simultaneously exposed to such factors as accelerations, noise, heat, changes in gas atmosphere, and emotional and physical stresses, the latter particularly during the launch and re-entry phases of the flight. Exposure to these factors during the re-entry phase follows a prolonged period of exposure to weightlessness, space radiation, isolation, and altered daily rhythms of activity. Hence, many Soviet specialists have emphasized the importance of research on the simultaneous effects of multiple spaceflight factors because of their concern that such complex factors evoke physiological responses that differ from the stereotyped response to individual factors. Combined factors may be mutually additive, synergistic, or antagonistic in effect. With an additive interaction, the effect of the combined factors is equal to the sum of the effect of each factor individually. With a synergistic interaction, the combined factors will evoke a greater response than the simple sum of the effect of each individual factor. With an antagonistic interaction, the overall effect is less than the sum of the effects of the individual factors. Thus, Soviet research on the effects of combined factors are roughly organized as follows:

Ionizing Radiation:
- Ionizing radiation and acceleration.
- Ionizing radiation and weightlessness.
- Ionizing radiation and altered gas atmospheres (hypoxia, hyperoxia etc.).

Weightlessness:
- Weightlessness and hypokinesia.

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[279] Tobias, C. A. et al. Ionizing radiation. Op. Cit.

Acceleration:
- Acceleration and hypodynamia.
- Acceleration and thermal factors.
- Acceleration and altered gas atmospheres.

Vibration:
- Vibration and acceleration.
- Vibration and hypoxia.
- Vibration and thermal factors.
- Vibration and ionizing radiation.

Superimposed upon the general classes of combined factors listed above are various physiological factors which also must be considered. These include biological rhythms, emotional and physical stress, and the general condition of the organism. Investigations of the effects of combined factors are particularly important because it has been noted that spaceflight factors, either individually or combined, alter sensitivity and reactivity thresholds to pharmacological preparations and other substances which are being contemplated to prevent or minimize the deleterious effects of spaceflight or to increase the resistance of the organism to the various spaceflight factors.[280-283]

While it is a common finding that the effects of combined spaceflight factors exceed or otherwise differ from the effects of individual factors, it has also been noted that one factor may increase the resistance of an organism to another. Such appears to be the case with hypoxia and ionizing radiations. As mentioned in Section VII of this chapter, short-term exposure to hypoxia (6 percent oxygen instead of the normal 20 percent) prior to irradiation has been found to have a distinct radioprotective effect in experiments with animals.[284] In contrast, short term (3 hour) exposure to an atmosphere rich in oxygen (98 percent) following irradiation has been found to have a negative effect on radiation tolerance and amplifies signs of radiation sickness.[285] These studies suggest that the oxygen content of artificial gas atmospheres can play an important role in resistance to and recovery from radiation damage.

While Soviet interest in the biomedical effects of combined spaceflight factors has been high since the mid-1960's, evaluation of those effects has been complicated by a lack of mathematical and computer technology with which to statistically process and analyze large volumes of parallel data. Therefore, there has been a growing effort in recent years to develop statistical techniques and models with which to cope better with complex biological systems and their interaction with multiple influences. The improvement of methods and equipment for such research will enhance the ability to plan biomedically for future prolonged spaceflights, in the opinion of Soviet specialists.[286]

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280 Tobias, C. A. et al. Ionizing radiation. Op. Cit.

281 Antipov, V. V. et al. Combined effect of flight factors. In: Foundations of Space Biology and Medicine. Vol. II, Ch. 17, Book 2. Washington, D. C., NASA, 1975, pp. 639–667

282 Lukyanova, L. D. Peculiarities of the energy metabolism in the central nervous system during the combined effect of vibration and irradiation. Space Biology and Aerospace Medicine (USSR), No. 2, 1975, 32–37.

283 Andrianova, L. A. The state of hypothalamic neurosecretory nuclei after a combined effect of acceleration and ionizing radiation. Space Biology and Aerospace Medicine (USSR), No.3, 1974, 14–17

284 Ovakimov, V. G. et al. Adaptation to hypoxia as a factor modifying its radioprotective effect. Medical Radiology (USSR), No.6, 1974, 49–53 (FRD # 1898)

285 Ivanov, K. V. et al. Changes in blood carboanhydrase activity in the organism after irradiation and exposure to increased oxygen pressure. Radiobiology (USSR), No.1, 1975, 124–126 (FRD # 2318)

286 Antipov, V. V. Combined effects of flight factors. Op. Cit.

D. RADIOPROTECTIVE COMPOUNDS AND SHIELDING

As is the case with the other spaceflight stresses thus far discussed, the Russians continue to search for promising pharmacological preparations which could be used to prevent or minimize the harmful effects of space radiation on the organism and to speed recovery from such effects. A vast number of compounds (more than 10,000 drugs) have been tested under laboratory and clinical situations. The basic classes of compounds include:

Preparations Which Affect Oxygen Metabolism:
- Increase cellular oxygen consumption.
- Decrease tissue respiration.

Free-Radical Preparations:
- Sulfhydrils.
- Bioamines.
- Chelates.
- Agents with enzyme activity.

Preparations Counteracting Biochemical Potentiation:
- Protecters of biological structures.
- Inactivators of enzymes.

Natural or Biologically Protective Agents:
- Amino acids.
- Polysaccharides.
- Vitamins.
- Hormones.

Central Nervous System Stimulants and Depressants.
Antibiotics.
Hematopoietic Stimulants.
Combinations of the Above Together With:
- Physical conditioning.
- Exposure to stresses (hypoxia etc.).

Of the large number of radioprotective drugs tested on various kinds of organisms, the most promising for human application are the mercaptoalkylamines, thiazolidines, indolylalkylamines, aminodisulfides, and a number of amino acids. Typical drugs which have received considerable attention in the Soviet literature include.

Cysteamine.
Cystamine dichlorhydrate.
Mercamine.
Aminoethyliosothiourea (AET).
Mercaptoethanolamine (MEA).
Serotonin (5 HT).
5-methoxytryptamine (5 MOT).
Para-amino-propiophenone (PAPP).
Crystaphos (sodium beta-aminoethylmonothiophosphate).[287-290]

Combined approaches to radiation protection are also being investigated. The use of metabolites such as ATP in combination with various drugs has decreased the severity of radiation sickness with a minimum of undesirable side effects. Combinations of sulfur containing and indolyalkylamine radioprotective drugs together with exposure to

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[287] Eydus, L. Kh. Physicochemical Foundation of Radiobiological Processes and Protection From Radiation. Moscow, "Atomizdat" Publishing House, 1972, 240 p.

[288] Guskova, A. K. et al. Radiation Sickness in Man. Moscow, "Meditsina" Publishing House, 1971, 382 p.

[289] Vasil'yev, P. V. et al. Chemical prophylaxis and therapy of radiation sickness. IN: Problems of Space Biology, Vol. 17. Moscow, "Nauka" Publishing House, 1971, 270–308 (FRD # 830)

[290] Vasin, M. V. et al. Radioprotective properties of indolylalkylaminoethanols. Radiobiology (USSR), No. 5, 1971, 779–781 (FRD #802).

stresses such as hypoxia have also shown promising results in animal experiments.[291 292]

The effects of radioprotective agents on vital organ systems such as the vestibular apparatus is also of concern since many of the agents under consideration affect vital nervous functions. Finally, there is concern that certain preparations which confer protection against radiation may reduce tolerance of other stresses associated with spaceflight.[293]

Despite the large Soviet effort in this field, there is little evidence that the radioprotective drugs investigated thus far are actually included in the Soviet spacecraft medical kit. This may be due to the fact that nearly all radioprotective compounds have various undesirable side effects which may be further potentiated by the spaceflight itself. There has been some speculation, however, that Soviet cosmonauts have been administered unspecified "prophylactic" radioprotective drugs prior to the flights of Soyuz 4 and 5. And a compound called "ambratine", a complex of vitamins, was listed as the only radioprotective preparation aboard the Soyuz 11/Salyut 1 complex in 1971. But there has been no further mention of the use of radioprotective preparations or drugs since that flight. In general, most Soviet experts in the field are of the opinion that the use of radioprotective agents thus far investigated is unrealistic and that other alternative methods of protection against radiation, such as shielding or the use of force fields, will have to be developed.[294 295]

As an alternative to radioprotective drugs, the Russians are investigating other approaches to crew protection during space missions. The most obvious approach is the use of certain materials to shield the entire spacecraft, certain compartments therein, or vital parts of the human body known to be particularly sensitive to the effects of ionizing radiations. This is a complicated problem because certain of the primary cosmic radiations are so powerful that no type of shielding could possibly stop them. In addition, there would be the problem of secondary radiations which occur when primary radiations pass through shielding or other materials. Nonetheless, Soviet investigators are calculating the parameters of shielding which would be necessary to minimize the effects of space radiations, particularly those from solar flares, during prolonged missions.[296]

E. NON-IONIZING RADIATIONS AND FORCE FIELDS

Radiations which do not produce ionization effects in biological tissues are also of some concern during spaceflights. These include the radiofrequency and microwave radiations emitted from radio and navigational equipment, electric and magnetic fields which might be used to deflect ionizing radiations in the event of a solar flare emergency, ultraviolet radiation from the Sun, and the visible and infrared

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[291] Sverdlov, A. G. et al. Relation of the hypoxic and protective effect of some radioprotectors. Radiobiology (USSR). No. 2, 1972. 221–228 (FRD #922).

[292] Antipov, V. V. et al. Study of the reactivity of the organism exposed to transverse accelerations and radioprotectors. Aerospace Medicine, No. 8, 1971, 72–81.

[293] Suslova, L. N. et al. Effect of radioprotectors on the functional state of the vestibular analyzer. Space Biology and Medicine (USSR), No. 2, 1973, 45–48.

[294] Janni, J. A. review of Soviet manned spaceflight dosimetry results. Aerospace Medicine, No. 12, 1969, 1547–1556.

[295] Gurovskiy, N. N. et al. Some results of investigations during the flight of the scientific orbiting station, Salyut. Op. Cit.

[296] Dudkin, V. Ye. et al. Analysis of the thickness of a radiation shelter for prolonged spaceflights. Space Biology and Aerospace Medicine (USSR), No. 4, 1975, 72–74.

radiations. Of present concern to Soviet space radiobiologists are the effects of electrostatic, and magnetic fields. This is apparently due to a parallel interest in the use of these fields to surround the spacecraft and act as a temporary shield against bursts of ionizing radiations. Considerable attention has therefore been given to the biological effects of very strong fields of this type on humans, animals, and microorganisms.[297-301]

VII. Gas Atmosphere and Pressures

The constant maintenance of an artificial spacecraft atmosphere which optimally satisfies the metabolic requirements of space crews is among the most vital problems in the space life sciences. Not only must the spacecraft atmosphere be totally reliable virtually 100 percent of the time, but its pressure and chemical composition must be constant within rigorous physiological limits. For this reason, Soviet and American research on the physiological effects of altered gas atmospheres and pressures has been and continues to be extensive.

Soviet research concentrates on those parameters of the gas atmosphere most vital to human physiology, namely, pressure and chemical composition. There is emphasis on the choice of diluent gases and the permissible limits of the partial pressures of oxygen (pO_2) and carbon dioxide (pCO_2), temperature, toxic substances, and other subtle parameters. The Soviet research effort, like the American one, is fundamentally subdivided into physiological investigations of the effects of oxygen-poor (hypoxic), oxygen-rich (hyperoxic), and carbon-dioxide variable (hypercapnic and acapnic) atmospheres as well as those containing a variety of inert gases including nitrogen, helium, neon, and argon. Pressure physiology includes investigations of the effects of high pressure (hyperbaric) and low pressure (hypobaric) atmospheres as well as studies of the physiological effects of rapid changes in pressure (compression and decompression). Finally, the influence of altered gas atmospheres on tolerance of and adaptation to other spaceflight factors such as confinement, isolation, accelerations, and radiation is receiving considerable attention.[302-305]

A. Hyperoxic Environments

While oxygen is necessary for life, in higher than normal concentrations it has distinct and complicated toxic effects on the organism. The persisting Soviet philosophy in the manned space program is to

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[297] Trukhanov, K. A. et al. Active Protection of Spacecraft. Moscow. "Atomizdat" Publishing House, 1970, 230 p.

[298] Unsigned. Honey comb in space (active protection of spacecraft with force fields). Chemistry and Life (USSR), No. 7, 1975, 26–28.

[299] Nakhil'nitskaya, Z. N. The biological effects of constant magnetic fields. Space Biology and Aerospace Medicine (USSR), No. 6, 1974, 3–15.

[300] Galaktionova, G. V. et al. Modification of the cytogenetic effect of ionizing radiation during exposure to constant magnetic fields. Space Biology and Aerospace Medicine (USSR), No. 6, 1974, 25–28.

[301] Stasyuk, G. A. Alterations in blood content after the short-term effect of a continuous magnetic field on the human organism. Physicians Practice (USSR), No. 12, 1973, 36–38 (FRD #1582).

[302] Malkin, V. B. Barometric pressure and gas composition. In: Foundations of Space Biology and Medicine. Vol. II. Ch. 1. Book 1. Washington, D.C., NASA, 1975, pp. 3–64.

[303] Sirotonin, N.N. The pathogenic effects of gas atmospheres. In: Pathological Physiology of Extreme States (P .D. Gorizontov et al, Eds.). Moscow, "Meditsina Publishing House, 1973, pp. 36–70 (FRD #1699).

[304] Agadzhanyan, N. A. The Organism and its Gas Environment. Moscow, "Meditsina" Publishing House, 1972, 246 p. (FRD #1317).

[305] Kotovskiy, Ye. F. Functional morphology during extreme states. In: Problems of Space Biology, Vol. 15. Moscow, "Nauka" Press, 1971, pp. 180–429.

provide the crew with an atmosphere as close in pressure and chemical composition to the terrestrial atmosphere as possible. In contrast, pure oxygen (pO_2=258 mm Hg) is utilized in the United States manned spaceflight effort.

There continues to be concern in the international bioastronautics community about the physiological effects of oxygen in increased concentrations at normal, increased, or decreased pressures. This research has application not only in manned space programs but in the manned undersea programs as well. Emphasis is on the specific pathological effects of hyperoxia, particularly on the central nervous system, respiratory organs, cells, and metabolism. There is also interest in the functional effects of oxygen on the human brain, respiratory, and cardiovascular systems. Adaptation to increased oxygen partial pressures is of importance relative to spaceflights of months or years in duration. Soviet scientists are concerned that not enough is known about the chronic effects of pure oxygen at relative low pressures (0.2–3.0 atmospheres). They are particularly interested in the adaptation of humans and animals to such atmospheres.[306, 307]

Specific mechanisms of the toxic action of high oxygen concentrations are receiving considerable attention. Particular emphasis is on the lungs and central nervous system and the role of the latter in the genesis of convulsions, which occur as a result of severe oxygen poisoning. Of concern is a general lack of data on the periods and amounts of time pure oxygen under normal and increased pressure may be used by healthy or diseased individuals.[308]

Methods of quickly detecting the toxic effects of oxygen on the central nervous system are being developed. A measurable reduction in the amplitude of electrical signals from the acoustic portion of the brain is a sensitive index of the effect of hyperoxic atmospheres on nervous and sensory systems.[309]

Recent investigations have also focused on the toxic effect of oxygen on endocrine and neurochemical systems. Studies indicate that an important factor in the pathogenesis of the toxic effects of hyperoxic environments is a disruption of the synthesis and breakdown of neural mediators.[310, 311] Oxygen at 4 atmospheres pressure causes an increase in ammonia and glutamic acid and a decrease in tissue glutamine which requires some 40 to 60 days to normalize in animals.[312] Pure oxygen has also been found to amplify the change caused by other factors, such as ionizing radiation, by inhibiting blood enzyme activity.[313]

Certain drugs are being investigated as a means of suppressing the toxic effect of oxygen. Some drugs which have been found to coun-

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[306] Zhironkin. D. G. Oxygen: Physiological and Toxic Effects. Leningrad. "Nauka" Press. 1972. 135 p. (FRD #1616).

[307] Agadahanyan, N. A. The organism and the gaseous environment. Op. Cit.

[308] Berezovskiy, V. A. Tissue Oxygen in Humans and Animals. Kiev, "Naukova Dumka" Publishing House, 1975, 277 p.

[309] Kammel, H. et al. Changes in acoustic brain evoked potentials in a normoxic and hyperoxic atmosphere. Space Biology and Aerospace Medicine (USSR). No. 4, 1975. 61–65.

[310] Yeremeyev, N. S. et al. Effects of increased partial pressure of oxygen on the sympathetic adrenal and acetylcholine systems. Physiological Journal (USSR), No. 15, 1972, 768–772 (JPRS 61376).

[311] Dudarev, V. P. et al. Gas exchange and certain blood indices during thyroid dysfunction. Space Biology and Aerospace Medicine (USSR), No. 2, 1975, 16–20 (FRD #2334).

[312] Gabibov. M. M. Ammonia, glutamine, and glutamic acid content in rat tissues during and after hyperoxia. Space Biology and Aerospace Medicine (USSR), No. 2, 1975, 12–16 (FRD #2333).

[313] Ivanov. K. V. et al. Changes in blood carboanhydrase activity in the organisms after irradiation and exposure to increased oxygen pressure. Op. Cit.

teract toxic effects have also been found to increase tolerance of low concentrations of oxygen.[314]

The interaction of oxygen and other gases on the physiological function of sensory systems such as the vestibular apparatus is of particular interest to Soviet space medicine specialists. As mentioned earlier, a gas mixture rich in oxygen and carbon dioxide (40–43 percent oxygen and 2 percent carbon dioxide) known as OCON–2 has been shown to prevent motion sickness and suppress latent vestibulo-autonomic disturbances. The mixture is apparently applied for a relatively brief period of time prior to or during exposure to simulated spaceflight conditions.[315]

Other beneficial uses of pure oxygen include its use in high pressure chambers to treat a variety of disorders and diseases including decompression sickness, and to counteract the negative effects of hypoxic atmospheres. But while research continues and large hyperbaric facilities are being constructed to further elucidate both the beneficial and detrimental effects of high oxygen concentrations, there is no indication of any trend toward the use of a low-pressure, pure oxygen atmosphere in Soviet manned spacecraft as is used in the American manned spaceflight program.[316]

B. HYPOXIC ENVIRONMENTS

Just as a hyperoxic atmosphere can be detrimental to health, so can an atmosphere deficient in oxygen (hypoxic). Because of the potential danger of accidental spacecraft cabin depressurization or life support system malfunction, there is considerable interest in the effects of different degrees of hypoxia on human physiology, psychology, and work capacity. Mechanisms of adaptation to hypoxic environments also continue to receive considerable attention. As is the case with research on hyperoxia, attention is focused on how hypoxia affects major organs and tissues.[317, 318]

Soviet research on the systemic effects of acute and chronic hypoxia is extensive. Of particular concern is the effect of oxygen deficiency on vestibular functions. One study has found that the effect of hypoxia combined with bedrest was insignificant, although bedrest itself decreased vestibular stability.[319] Another test in which 40 human subjects breathed a hypoxic mixture (10.5 percent oxygen) for 30 minutes at a time revealed that hypoxia increased vestibular sensitivity to rotatory accelerations and generally decreased vestibular stability. This approach is now used to detect latent vestibular sensitivity in pilot and cosmonaut candidates.[320]

Cardiovascular responses to hypoxia are also being investigated. Disturbances in the rhythm of cardiac function are noted in subjects exposed to a hypoxic environment. One type of disturbance indicates reduced tolerance of hypoxia while another type has no effect on

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[314] Brestkina, L. M. et al. Effect of 1,4-benzodiazepin derivatives on the toxic effect of oxygen under increased pressure. Pharmacology and Toxicology (USSR), No. 2, 1975, 216–220.

[315] Markaryan, S. S. et al. Effect of increased oxygen and carbon dioxide content on vestibular tolerance. Op. Cit.

[316] Unsigned. New Moscow hyperbaric oxygenation "barohospital". Medical Gazette (USSR), April 18, 1975, p. 4 (FRD #2380).

[317] Agadzhanyan, N. A. The organism and its gaseous environment. Op. Cit.

[318] Kolovskiy, Ye. F. et al. Functional morphology during extremal actions. Op. Cit.

[319] Vasil'yev, A. I. et al. Hypokinetic effect on vestibular function in an altered atmosphere. Space Biology and Aerospace Medicine (USSR), No. 4, 1975, 58–61.

[320] Sidel'nikov, I. A. et al. Threshold sensitivity of the vestibular analyzer during hypoxia. Space Biology and Aerospace Medicine. No. 6, 1974, 55–58.

tolerance. A combination of tests involving the injection of potassium chloride, orthostatic probes, and physical exercises are recommended to detect latent cardiovascular intolerance to hypoxic conditions.[321]

Considerable attention is given to respiratory responses to hypoxia both at the primary (lung) and secondary (blood) level. Hypoxic environments change lung tissue and blood chemistry and affect the blood forming (hematopoietic) system. The nature of these changes are used as indices of tolerance of or adaptation to hypoxia.[322, 323]

Changes in the function and morphology of other organs in response to acute or chronic hypoxia are also investigated. These include the liver and kidneys, endocrine glands, gastrointestinal tract, and the immune system. General functional changes are also documented in human and animal subjects exposed to hypoxia arising from simulated failures in environmental control systems.[324-328]

While many investigations of the systemic effects of hypoxia are conducted under acute (rapid onset) conditions, there is a large Soviet research effort to investigate the effects of chronic (gradual onset) hypoxia. These studies are conducted in facilities located in mountainous regions of the Soviet Union as well as in polar regions. The purpose of this research is to evaluate physical and psychological work performance, elucidate mechanisms of adaptation, and develop approaches for facilitating adaptation to hypoxic environment.[328a-328c]

While the specific cellular and biochemical mechanisms of adaptation to hypoxia remain elusive, it is clear that there is a definite process of adaptation. Two approaches to facilitating adaptation involve preconditioning in a pressure chamber or moderate high altitude and the addition of carbon dioxide to an oxygen deficient atmosphere. The carbon dioxide stimulates respiration and improves the efficiency of oxygen uptake. Altitude resistance improves after pressure chamber exposure. As mentioned earlier, resistance to other spaceflight factors such as accelerations has been demonstrated in Soviet studies to improve after prolonged adaptation to high altitudes. Accordingly, high altitude training centers are extensively used by Soviet cosmonauts.[328d]

There has been a considerable amount of Soviet research on pharmacological preparations which increase resistance to the detrimental

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[321] Malkin, V. B. et al. Electrocardiographic changes during acute hypoxia and their importance. Space Biology and Aerospace Medicine (USSR), No. 2, 1974, 54–61.

[322] Yumatov, Yu. A. Respiratory index dynamics of arterial blood, cerebrospinal fluid, and tissue from the bulbar respiratory center during Hypoxia. Physiological Journal (USSR), No. 4, 1975, 600–609 (FRD #2375).

[323] Tavrovskaya, T. V. et al. Quantitative characteristics of erythropoiesis in humans and animals adapted to prolonged hypoxia. Bulletin of Experimental Biology and Medicine (USSR), No. 1, 1975, 18–21 (FRD #2205).

[324] Nazarenko, A. I. Influence of experimental circulatory hypoxia on tissue respiration and glycolysis of the liver and kidneys. Physiological Journal (USSR), No. 3, 1975, 377–380 (FRD #2427).

[325] Gribanov, G. A. Phospholipid metabolism in endocrine organs during acute hypoxia. Space Biology and Aerospace Medicine (USSR), No. 2, 1975, 9–12 (FRD #2332).

[326] Babkina, O. I. et al. Effect of different atmospheres on active transport of glucose in the small intestine of rats. Space Biology and Medicine (USSR), No. 5, 1971, 22–26.

[327] Durnova, G. N. et al. Effects of hypoxia on the function and metabolism of alveolar macrophages. Bulletin of Experimental Biology and Medicine (USSR), No. 3, 1975, 113–115 (FRD #2358).

[328] Popkov, V. L. et al. Functional and morphological changes during lethally increasing hypoxia and hypercapnia. Space Biology and Aerospace Medicine (USSR), No. 4, 1974, 24–28.

[328a] Aydraliyev, A. A. et al. Change in human work capacity under high altitude conditions. Space Biology and Aerospace Medicine (USSR), No. 4, 1975, 83–84.

[328b] Petrukhin, V. G. et al. Effect of repeated exposure to a rarified atmosphere on the animal and human organism. Space Biology and Aerospace Medicine (USSR), No. 3, 1975, 53–56 (FRD #2476).

[328c] Dudarev, V. P. et al. Symposium, "Molecular Foundations of Adaptation to Hypoxia" (a review). Physiological Journal (USSR), No. 2, 1974, 273–274 (FRD #1755).

[328d] Malkin, V. B. Barometric pressure and gas composition. Op. cit.

effects of hypoxia and other altered gas atmospheres. For example, the widely used drug, reserpine, has been found to increase significantly tolerance of hypoxia due to its cholinergic action and its effect on oxidative processes. The mechanism of effect of many other preparations used to facilitate adaptation or increase resistance to hypoxia, hyperoxia, or hypercapnia is being investigated. Of particular importance are the cardiovascular, narcotic, anesthetic, allergenic, or other side effects of these experimental drugs. The pharmacological potentiation of the radioprotective effect of hypoxia is also being investigated as mentioned earlier.[328e-330]

C. CARBON DIOXIDE, CARBON MONOXIDE, AND THE INERT GASES

While carbon dioxide in somewhat higher than normal concentrations has been found to have a beneficial effect on human tolerance to such stresses as hypoxia and acceleration, the gas becomes toxic at high concentrations. The terrestrial atmosphere contains a small amount of the gas (0.03 percent). A tenfold increase in carbon dioxide does not have a substantial effect on human vital activity and work capacity. But beyond this point, a substantial increase in carbon dioxide affects the central nervous system, cardiopulmonary system, acid-base equilibrium in the blood, and mineral metabolism. The gas is therefore of concern relative to the potential failure of spacecraft environmental control systems because man at rest yields about 400 liters of carbon dioxide per day as a by-product of respiration. The acute and chronic effects of carbon dioxide are summarized in Figure 4–8 and Table 4–14.

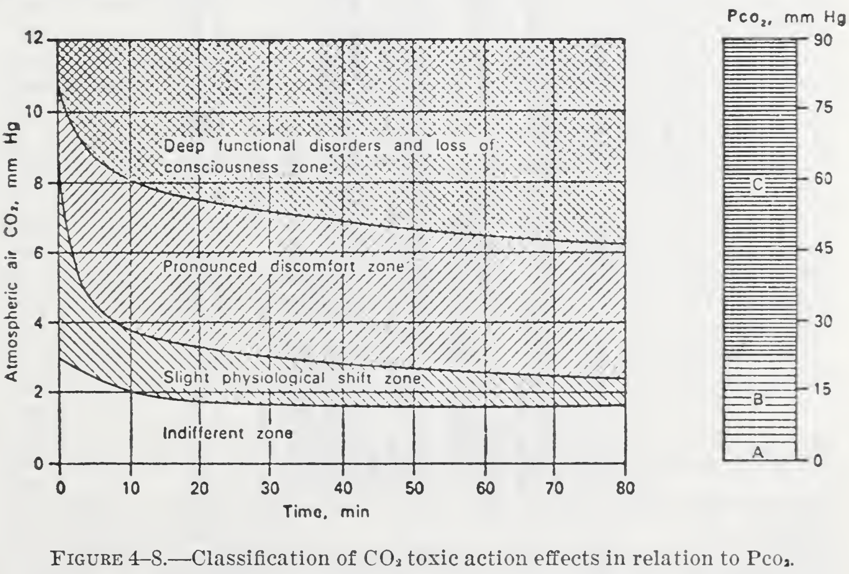

FIGURE 4–8.—Classification of CO_2 toxic action effects in relation to P_{CO_2}.

Source: Malkin, V. B. Barometric pressure and gas composition. In Foundations of Space Biology and Medicine. vol. II, ch. 1, Washington, D.C., NASA, 1975, pp. 3–64.

[328e] Markova, Ye. A. et al. Mechanisms of the antihypoxic action of reserpine. Pathological Physiology and Experimental Therapy (USSR). No. 2, 1975. 68–69 (FRD #2416).
[329] Vasil'yev, P. V. et al. Pharmacological substances and resistance of the organism to atmospheric changes: The effect of hypoxia and hypercapnia on the organism. In: Problems of Space Biology. Vol. 17. Moscow, "Nauka" Press, 1971, pp. 10–82 (FRD #825).
[330] Ovakimov, V. G. et al. Pharmacological potentiation of the radioprotective effect of hypoxic hypoxia. Radiobiology (USSR), No. 6, 1974, 859–863 (FRD #2374).

TABLE 4-14.—TOXIC EFFECTS OF ELEVATED CO_2

PCO_2 in AGA, mm Hg	Nature of manifestation of toxic action of CO_2 on human organism	Time at rest	Performance of physical load	Performance of mental work
1. To 7.5	No unpleasant sensations; no functional changes detected	Up to 3–4 months	Possible (all kinds)	Possible.
2. To 15.0	No subjective symptomatics; some rise in minute respiration volume noted; development of limited acidosis.	Up to 30 d	Of light and moderate intensity.	Possible.
3. To 25.0–30.0	State of discomfort; dyspnea especially during work; increase in minute volume of respiration 2–2.5 times the rest value; for exposure longer than 3 d, readily reversible changes in metabolic processes, followed by acidosis.	Up to 7 d	Heavy work is difficult. Light work is possible. Moderate work is restricted. Heavy work is extremely difficult.	Possible for formulated stereotype.
4. To 35.0–40.0	Dyspnea even at rest, "heaviness" in head, dizziness, increase in minute volume of respiration 3–4 times with relative stability of indicators of the functioning of the cardiovascular system; respiratory acidosis; disturbances of activity of cerebral cortex, disturbance of sleep.	Up to 15 h	Light work is restricted. Moderate work is extremely difficult.	Restricted even for routine mental work.
5. To 50.0	Dyspnea; headache, dizziness; disturbance of vision, disturbance of sleep, increase in minute volume of respiration of 4–5 times, respiratory acidosis, pronounced shifts of the functioning of the cardiovascular system; tachycardia, rise in arterial pressure; disorders of the activity of the central nervous system.	Up to 3–4 h	Heavy work is impossible. Light work is difficult. Moderate and heavy work are impossible.	Difficult.
6. To 60.0	Intense rise in subjective and objective symptomatics	Up to 1 h	All Kinds of work are impossible.	Impossible.
7. Above 60.0 but not more than 75.0.	Acute intensification of subjective and objective symptomatics	Up to 15 min	Excluded	Excluded.

SOURCE: Malkin, V. B., Barometric pressure and gas composition. In: Foundations of Space Biology and Medicine. Vol. II, Ch. 1, Wash., D.C., NASA, 1975. pp. 3–64.

Soviet research has indicated that prolonged exposure to elevated carbon dioxide (above 7.5 mm Hg) is undesirable because of chronic toxicity. In an artificial gas atmosphere to be used for 3 or 4 months, the pCO_2 must not exceed 3–6 mm Hg. Investigations continue to determine the optimum limits of carbon dioxide in artificial gas atmospheres to be respired for long periods of time. The positive effect of carbon dioxide on tolerance of hypoxia and other stresses is also receiving considerable attention.[331–333]

Carbon monoxide is also a gas of concern in the artificial gas atmosphere because it is extremely toxic at very low concentrations. Several investigations in which animals have been exposed to this gas have been conducted. These studies have indicated that spaceflight factors such as hypokinesia decrease resistance to the gas. Exposure to oxygen-rich environments facilitates the elimination of carbon monoxide while not significantly altering resistance to it. The studies indicate that the permissible concentration of carbon monoxide in spacecraft should not exceed and should perhaps be less than the permissible limit allowed under industrial conditions.[334–335]

The use of inert diluent gases such as helium in artificial gas atmospheres is receiving considerable attention in the Soviet and American space and undersea life sciences communities. Both Soviet and American investigations of man and animals chronically exposed (up to 60 days) to helium-oxygen and helium-nitrogen-oxygen atmospheres at normal pressure have revealed no unfavorable effects on metabolism, respiration, circulation, or central nervous function. Although terrestrial life forms are accustomed to nitrogen in the atmosphere, its absence has not been found to be of serious biological significance. Human mammalian cell cultures exposed to helium-oxygen atmospheres for up to 10 generations have revealed no noticeable shifts from normal. The only feature which has been found to differentiate biologically helium from nitrogen is the thermophysical property of the former which intensifies thermoregulatory processes because of its high heat conductance. In one recent Soviet experiment, however, a helium-oxygen atmosphere was found to increase the tolerance of human subjects to accelerations of 4–8 G. The positive effect was attributed to an intensification of respiration and an elevation of pulmonary ventilation and gas exchange possibly associated with a decline in aerodynamic resistance to breathing. Thus, there appear to be few if any biomedical barriers to the use of helium and certain other of the inert gases at normal pressure in an artificial atmosphere. Indeed, helium is commonly used as a diluent gas in hyperbaric deep-diving atmospheres. However, there is no indication that diluent gases

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[331] Malkin, V. B. Barometric pressure and gas composition. Op. Cit.

[332] Glazkova, V. A. et al. Acid base balance in the blood respiration of hypercapnic gas mixtures. Space Biology and Aerospace Medicine (USSR), No. 2, 1975, 20–27 (FRD #2335).

[333] Deynega, V. G. et al. Effect of an altered atmosphere and increased temperature on human respiration and gas exchange in a small enclosure. Space Biology and Aerospace Medicine (USSR), No. 6, 1974, 58–63.

[334] Abidin, B. I. et al. Effect of restricted activity on resistance to the acute effect of carbon monoxide. Space Biology and Medicine (USSR), No. 2, 1973, 30–33.

[335] Abidin, B. I. et al. Effect of high oxygen content on the intensity of formation and elimination of some gaseous products. Space Biology and Medicine (USSR), No. 4, 1972, 6–9.

other than nitrogen are being contemplated for use in the Soviet manned spaceflight effort.[336-338]

D. PRESSURE EFFECTS

The pressure of an atmosphere determines the physiological action of its chemical constituents. Figure 4–9 depicts this pressure/gas relationship in an artificial gas atmosphere (AGA) as it concerns the physiological action of oxygen.[339]

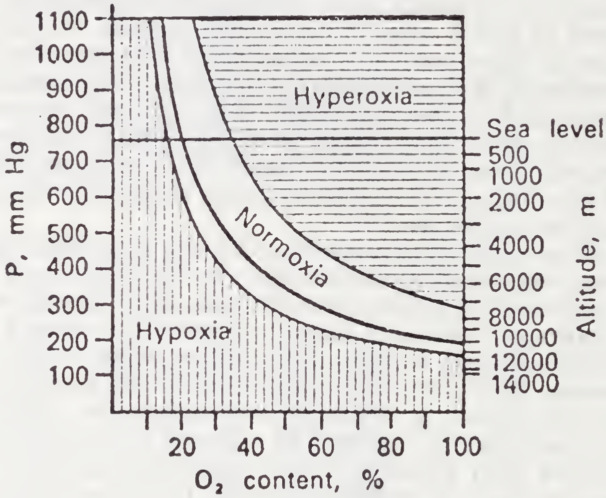

FIGURE 4–9.—PO_2 of the AGA as a function of barometric pressure. Three zones of oxygen supply: hypoxia, normoxia, and hyperoxia.

Source: Malkin, V. B. Barometric pressure and gas composition. In Foundations of Space Biology and Medicine. Vol. II., Ch. 1., Washington, D.C., NASA, 1975, pp. 3–64.

The atmospheric pressure used in Soviet and American spacecraft differs substantially. As discussed earlier, a normal terrestrial atmosphere of 760 mm Hg is used in Soviet spacecraft while a pure oxygen atmosphere at 258 mm Hg has been used in the American Mercury, Gemini, Apollo, and Skylab programs. In both cases, space crews are provided with the oxygen necessary for optimum physiological performance.

The danger of sudden or even gradual space cabin depressurization in the vacuum of space, while remote, is nonetheless always a factor to be reckoned with, as the tragic fate of the Soyuz 11 demonstrated. Therefore, Soviet researchers have devoted considerable effort to the study of the physiological effects of altered atmospheric pressures, including gradual and explosive decompression, altitude decompres-

[336] Sushkov, F. V. et al. Biological evaluation of the effect of an oxygen-helium atmosphere on cell cultures. Space Biology and Medicine (USSR), No. 4, 1973, 38–43.
[337] Troshikhin, G. V. Heat regulation in a hypoxic atmosphere with nitrogen-helium dilution. Space Biology and Medicine (USSR), No. 6, 1972. 23–27.
[338] Kamenskiy, Yu. N. et al. Effectiveness of a helium oxygen atmosphere during transverse accelerations. Space Biology and Aerospace Medicine (USSR), No. 4, 1975, 53–58.
[339] Malkin, V. B. Barometric pressure and gas composition. Op. Cit.

sion sickness, general dysbarism, and the etiology and pathogenesis of bubble formation in decompression sickness. Activity in this field has been particularly high since the Soyuz 11 incident. Emphasis has been on detailed physiological analyses of decompression disorders and approaches to preventing or minimizing the damaging effects of various types of decompression phenomena. This research also parallels manned undersea research. Space oriented research tends to concentrate on the physiological effects of normal and decreased atmospheric pressure while undersea research focuses on decompression from high hydrostatic pressures.[340, 341]

There are three fundamental causes of decompression disorders. First, elevated pressure and damage therefrom in body cavities is the result of the difference between high internal and low external pressure which can occur during explosive or rapid decompression. Second, saturated gas can form bubbles in body fluids or tissues during decompression from high to normal or from normal to low atmospheric pressure. Finally, actually boiling and vaporization of body fluids with severe damage to surrounding tissues can occur during rapid or explosive decompression from a normal atmospheric pressure to one approaching a vacuum state. Soviet research has concentrated mainly on gradual or altitude decompression disorders with emphasis on the mechanisms of effect of decompression on the function and morphology of organs, tissues, and biological fluids of animals. Changes in respiration, circulation, and detailed analyses of gas composition and other indices of the blood are also examined.[342, 343]

The ultimate purpose of Soviet research on decompression disorders is to develop methods for preventing, increasing resistance to, or protecting individuals from the unfavorable consequences of these factors. Recent research has examined the application of low pressure (hypobaric) mixed-gas atmospheres as a method of preventing altitude decompression disease. It was demonstrated experimentally that the development of decompression sickness can be prevented by preliminary desaturation for 6 to 8 hours in a nitrogen (60 percent) and oxygen (40 percent) atmosphere maintained at 550 mm Hg (760 mm Hg is normal atmospheric pressure). It is speculated that the application of this method in a spacecraft cabin could prevent decompression sickness should cabin pressure decrease to 250 mm Hg or pressure in an extravehicular activity (EVA) suit decrease to 180–200 mm Hg. Experiments have involved tests of variations of the above. Exposure to a 100 percent oxygen atmosphere for 5 hours or to an oxygen-nitrogen atmosphere for 10 hours at 430 mm Hg has been demonstrated to be an effective method for preventing decompression sickness in human subjects working in a low pressure (200 mm Hg) atmosphere for 5–6 hours. Other approaches designed to prevent or treat decompression disorders include cardiovascular and respiratory

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[340] Ibid.

[341] Gramenitskiy, P. M. Decompression disorders. In: Problems of Space Biology. Vol. 25. Moscow, "Nauka" Press, 1974, 349 p.

[342] Ivanov, K. V. et al. Blood changes during decompression sickness after forced decompression. Hygiene, Labor, and Occupational Diseases (USSR), No. 5, 1975, 36–39 (FRD #2458).

[343] Bogoslovov, G. B. Pathogenesis of some respiratory and circulatory reactions accompanying drops in barometric pressure. Space Biology and Medicine (USSR), No. 6, 1972, 27–29.

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stimulation, general physical conditioning, and the use of various therapeutic decompression or recompression regimens.[344-346]

E. RESPIRATION AND TOXICOLOGY

Soviet scientists continue to develop methods for monitoring the dynamics of respiratory function and the chemical composition of space cabin atmospheres and respired air under spaceflight conditions in order to evaluate and maintain the medical condition of crew members. Equipment is being developed for the continuous analysis of expired alveolar air. Methods of evaluating respiratory function under the influence of spaceflight factors such as acceleration and weightlessness are being examined. Changes in the dynamics of oxygen consumption and tolerance of stresses during and after restricted activity are being investigated. Recent animal experiments indicate that prolonged hypokinesia (60–100 days) severely disrupts oxygen metabolism in response to physical exercise. Normalization of oxygen metabolism requires up to two months.[347-349]

There is continuing concern about the accumulation of toxic substances in artificial atmospheres particularly during long stays by crews. Of particular concern are spacecraft cabins, submarines, and undersea research vehicles. Accordingly there is considerable research on methods of monitoring artificial gas atmospheres and of preventing excessive contamination by toxic substances. The toxicological characteristics of a variety of man-made compounds used in space and undersea vehicles are being evaluated. The out-gassing of volatile substances from polymers, plastics, and other structural materials as a function of their aging and the influence of these substances on human health is of continuing concern. Fortunately, there have been no problems of a severe or fatal toxicological nature in the Soviet and American spaceflight missions flown thus far, save the recent Apollo-Soyuz re-entry episode in which propellant vapors were breathed by Apollo astronauts during the final descent phase.[350-353]

VIII. Space and Exobiology

A. THE BIOSATELLITE PROGRAM

The Soviet biosatellite program has been more prolific than its American counterpart. A programmatic description and summary of

[344] Genin, A. M. et al. Hypobaric nitrogen-oxygen atmospheres as a method of preventing altitude decompression disease. Space Biology and Aerospace Medicine (USSR), No. 3. 1975, 48–52 (FRD #2475).

[345] Genin, A. M. et al. Search for effective procedures of denitrogenization of the human body to prevent altitude decompression sickness. Space Biology and Medicine (USSR), No. 3, 1973, 34–39.

[346] Chernyakov, I. N. et al. Prevention of altitude decompression disease during flight in a pressurized cabin. Military Medical Journal (USSR), No. 4, 1975, 85–88 (FRD #2414).

[347] Mishchenko, V. S. et al. Sampling alveolar air for a continuous gas analysis. Physiological Journal (USSR), No. 3, 1975, 415–417 FRD #2451).

[348] Belkaniya, G. S. Respiratory function and gravity. Space Biology and Aerospace Medicine (USSR), No. 2, 1975, 3–8 (FRD #2331).

[349] Kovalenko, Ye. A. et al. Physical performance and oxygen supply following prolonged hypokinesia. Space Biology and Aerospace Medicine (USSR), No. 1, 1975, 13–20 (FRD #2280).

[350] Yablochkin, V. D. Development of measures for preventing contamination of enclosed atmospheres. Space Biology and Aerospace Medicine (USSR), No. 4, 1975, 27–30.

[351] Solomin, G. I. et al. Toxicological evaluation of ethyl acetate in the atmosphere of closed modules. Space Biology and Aerospace Medicine (USSR), No. 2, 1975, 40–44 (FRD #2039).

[352] Dvoskin, Ya. G. Significance of polymers as one external environmental factor in the incidence of crew illness on sea-going vessels. Hygiene and Sanitation (USSR), No. 11, 1974, 98–100 (FRD #2354).

[353] Wands, R. C. Toxicology of the air in closed spaces. In: Foundations of Space Biology and Medicine, Vol. II, Ch. 2, Book 1. Washington, D.C., NASA, 1975, pp. 65–93.

that program from its beginnings to date is provided in Chapter Three, Table 3–5 (p. 233).

The purpose of the Soviet biosatellite program has been to complement the manned spaceflight effort by investigating in considerable depth the influence of various spaceflight factors on animals (as high as dogs, taxonomically), higher and lower plants, lower life forms (insects and other invertebrates), and micro-organisms. Actually, biological experiments have been conducted not only on spacecraft specifically designed for space biological missions, but on most of the manned missions and on a few of the unmanned missions. For example, since 1970, biological experiments have been carried along on virtually all of the Soyuz/Salyut series of manned spaceflights. In the 1971 flight of Soyuz 10, frog embryos were carried along to investigate the effects of weightlessness on the development of the vestibular analyzer and nervous system. On the 8 day Soyuz 13 flight of 1973, a special biological capsule called "Oazis 2" was carried along so that the effects of spaceflight factors on the algae, Chlorella, duckweed, and various bacteria could be investigated. On the most recent Soyuz 17,18/ Salyut 4 flights of 1975, the "Oazis" biocapsule was used once again for studies of bacteria, insects (fruit flies), animals (frog eggs and live hamster tissue) and plants (algae and peas) under the most prolonged spaceflight conditions yet provided on a Soviet manned flight (63 days). Biological experiments have also been carried along on the American Apollo/Skylab series. It was reported that the effects of space radiation on plant seeds was investigated on the unmanned Soviet satellite Kosmos "610" of 1974, although how this was accomplished is not known. Possibly, the "610" was a typographical error and the actual number was "690," which was a bona fide biosatellite.[354-358]

Since 1970, there have been three major programs of biological experimentation for which an unmanned Kosmos spacecraft was specifically designed. The Kosmos 605 was a biosatellite designed for the support of a large number and wide variety of organisms including rats, tortoises, insects, plants, fungi, and bacteria. Major innovations in Soviet biosatellite technology included:

Orbiting the largest number of test animals by any country thus far;

Obtaining a second generation of insects in space;

Development of a method for tabulating the movements of rats by using the animals as cores of weak magnetic fields generated within their compartments aboard the spacecraft; and

Testing the effect of an electrostatic force field around the spacecraft exterior to deflect space radiations.

As mentioned in Section VI, the Russians appear to be intent upon the use of force fields to protect future spacecrews from ionizing radiations.[359, 360]

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[354] Grigor'yev, Yu. G. et al. Physical and Radiobiological Investigations on Artificial Earth Satellites. Moscow. "Atomizdat" Press, 191 p. (NASA TT–F–724).

[355] Vinnikov, Ya. A. et al. Comparison of the development of the vestibular apparatus of the frog in weightless and normal states. Journal of Evolutionary Biochemistry and Physiology (USSR), No. 3, 1972, 343–346 (FRD #959).

[356] Some results of the Soyuz-19 flight. Izvestiya (USSR). Feb. 21, 1974, p. 5 (FRD #1683).

[357] Soyuz-17/Salyut-4 Biological experiments. Pravda (USSR), Jan. 21, 1975, p. 2 (FRD #2198).

[358] Biological experiments on Soyuz 18/Salyut 4 and Kosmos 610. Pravda (USSR), June 10, 1975, p. 6.

[359] Kosmos 605 biosatellite. Nature (USSR), No. 6, 1974, 91–92 (FRD #1894).

[360] Soviets gain biological data from Kosmos 605. Aviation Week and Space Technology, April 1, 1974, p. 40.

The automated life support system on the Kosmos 605, and later on the essentially similar Kosmos 690, performed reliably. Rats were housed in individual cylindrical containers with upper and lower compartments. The animal occupied the upper compartment while the lower one was used for automatic waste collection. Each container had a circuit acting as an induction coil to register the movement of the animals. Ventilation, food, and water (every 6 hours) as well as light (0800–1600 hours daily) were automatically programmed. If an animal showed no movement for 24 hours, life support inputs were shut off and the container was hermetically sealed.[361, 362]

The 22-day Kosmos 605 flight was the most elaborate biological experiment in space yet conducted by the Soviet Union. Accordingly, the results of the experiment are the most comprehensive to have ever been published. The official report of the experiment, as translated for NASA internal use, is 432 pages long. Major findings from the rat experiments included:

deterioration of tissue respiration
reduction in body temperature
decrease in muscle and bone mass and strength
changes in the weight of endocrine glands, spleen, and kidney
decreased food intake

At the same time, no acute pathological changes were noted in rats after the 22 day flight. A group of animals allowed to recover after the flight for 3–4 weeks did not differ from their non-flight controls.[363, 364]

Land tortoises (Testudo horsefieldii) were also flown aboard the Kosmos 605 as they had been on the earlier Zond 5 and Zond 7 flights of the late 1960's. Changes in skeletal and cardiac muscles and in bone density were the focus of attention in these experiments. [Young-adult animals weighing 250–300 grams were used.] A total of 30 animals were studied, of which 6 were flown on Kosmos 605. No statistically significant changes in muscle or bone mass were noted which could be attributed to the 22 day flight. Most significant changes noted were due to the fact that the animals were not fed during the flight. No changes were noted in the developed or developing bone tissue of the shell or major supporting bones. Many controlled American studies of newly hatched land turtles subjected to chronic (months in duration) accelerations, immobilization, and simulated weightlessness have indicated that these factors, particularly exposure to clinostats and immobilization, can cause rapid and striking morphological changes (shell deformation) in the soft, developing turtle shell. There have been no American space experiments to determine the effects of true weightlessness on this phenomenon. Since fully developed, fasting tortoises with hard shells have been used in relatively short-duration Soviet flights, it is not possible to compare the results of Soviet and American experiments.[365, 366]

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[361] Life support system on biosatellites Kosmos 605 and Kosmos 690. Leningrad Pravda (USSR), Dec. 31, 1974, p. 2 (FRD #2233).

[362] Gazenko describes Soviet Biosatellite experiments. Pravda (USSR), March 1, 1974, p. 3 (FRD #1697).

[363] Results of Scientific Investigations on Kosmos 605. Washington, D.C., NASA, 1974. 432 p. (in-house translation).

[364] Life during weightlessness. Izvestiya (USSR), March 2, 1974, p. 5.

[365] Results of Scientific Investigations on the Kosmos 605 Satellite. Op. Cit.

[366] Wunder, C. C. et al. Gravitational force as a determinant of turtle shell growth and shape. Aerospace Medicine, No. 6, 1974, 623–629.

No statistically significant genetic or other changes were noted in fruit flies or their progeny after the flight. But mushrooms grown during the flight were greatly deformed with long twisted stems and large root systems. Similar deformation changes have been noted in plants after earlier Soviet biosatellite experiments. The implication of these findings is that certain types of developing tissues are quite sensitive to gravitational influences.[367]

The use of an electrostatic field as a shield against space radiations was successful. The field was found to significantly decrease the radiation dose inside the spacecraft. This finding augurs well for the application of this method in future Soviet manned spacecraft.[368]

The Kosmos 690 flight of late 1974 was a follow-on to the Kosmos 605 flight of a year earlier. The major objective of the 20 day flight was to investigate the combined effect of weightlessness and radiation on animals. A total of 35 rats were specially trained to eat and drink under weightless conditions. After 10 days of flight, conditions of acute radiation, as would be emitted by a powerful solar flare, were stimulated by means of an artificial Cesium 137 source of gamma radiation for a period of 24 hours (32 rad/hour average power). Doses received by the animals ranged from 200 to 1000 rad (1200 to 1300 rad is lethal). Other biological experiments were conducted with yeasts and plant seeds. Once again, electrostatic force fields were tested as a means of shielding from space radiation.[369]

While Soviet scientists are continuing the development of more sophisticated biological satellites, there has been no counterpart American biosatellite effort since the flight of Biosatellite 2 in 1967. Since that time, American biological experiments have been included in manned missions, including the 84 day Skylab flight. But there will be no specific biosatellite effort in this country until the early 1980's when the space shuttle system becomes operational.[370]

Meanwhile, American space biologists have participated in the Soviet Kosmos 782 biosatellite program in November, 1975. American experiments involved the exposure of a series of small biological samples (fruit flies, plant tumors, and fish eggs) to spaceflight conditions as well as participation in pre- and post-flight analyses of tissues from Soviet and Czechoslovakian rat experiments. The overall weight of the biological package aboard Kosmos 782 was about one ton. Once again, Central Asian tortoises were used by the Russians to evaluate the effects of artificial gravity. One group of tortoises remained on a centrifuge for the duration of the 22 day flight, another group remained in a weightless state aboard the spacecraft, and a third group served as a control on Earth. In another experiment designed by Soviet, French, and Romanian scientists, the effect on living cells of exposure to galactic space radiation was investigated. Layers of plant seeds (lettuce, tobacco, and others) separated by layers of detection material provided information on changes in the cells caused by radiations. Seed propagation under conditions of weightlessness and artificial gravity was studied preparatory to the future develop-

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[367] Soviets gain biological data from Kosmos 605 flight. Op. Cit.

[368] Results of Scientific Investigations on the Kosmos 605 satellite. Op. Cit.

[369] Kosmos 690 biological experiment. Pravda (USSR), Dec. 24, 1974, p. 3 (FRD #2152).

[370] Saunders, J. F. (Ed.), Experiments of Biosatellite II. Washington, D.C., NASA, 1971, 352 p. (NASA SP–204).

ment of closed-cycle life support systems. A large group of bacteria-free rats provided by Czechoslovakian researchers was used to study the effect of weightlessness and spaceflight on infection resistance and immune responses.[371] More elaborate American experiments are planned for future Soviet biosatellite missions.

Most recently, a Soviet spacecraft designed for manned flight, the Soyuz 20, was reconfigured as a biological satellite in order to extend substantially the mission duration of space biological experiments. The Soyuz 20 was docked with the now-unmanned Salyut 4 space station beginning November 19, 1975. The experiment was for 90 days duration, a new record for a biosatellite.[372]

Comprehensive biological experiments with different plants and animals were simultaneously conducted on Soyuz 20. Experiments with turtles were once again designed to assess the effect of gravitational factors on vertebrate organisms. Experiments with fruit flies were designed to assess the effects of gravitational factors on genetics, growth and development. Some 20 species of higher plants were grown in special compartments to investigate their molecular structure and to assess radiation effects. The influence of space flight factors on different micro-organisms was also under study preparatory to the design of new life support systems. Many of the experiments on Soyuz 20 were continuations of those conducted on Kosmos 782. However, the microclimate of the Soyuz 20 differed from that of the Kosmos 782 which may have an interesting effect on experimental results.[373]

The Russians are continuing to upgrade the technology of their biological satellites, particularly life support technology. Efforts are being made to limit the amount of toxic substances in the biosatellite atmosphere and to improve food and waste management and monitoring (biotelemetry) equipment. Experiments with animals in biosatellite mockups are designed to establish standards for a variety of contaminants such as ammonia.[374]

The results of Soviet biosatellite experiments conducted thus far have not yielded data of a startling nature which would negatively affect the manned spaceflight effort. Data from animal studies in space have tended to complement data from manned flights. Much of the data on genetic and cellular studies has been inconclusive or statistically insignificant, given the relatively short duration of the experiments until only recently. The results of most biological experiments in space conducted both by the Russians and Americans support the general conclusion that spaceflight factors do not significantly interfere with growth, development, cell division, and mutagenic processes nor do they appear to modify radiation effects. Nonetheless, the advantages of animal experimentation in space are many, not the least of which is the fact that animals can be subjected to more rigorous experimental stresses and detailed analyses. For these and many other reasons, the Russians apparently feel that space biological

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[371] Biological experiments on Kosmos 782: Developing a biological data base for interplanetary manned flight. Trud (USSR), Nov. 27, 1975, p. 2 (FRD #2856).

[372] Flight of the Salyut 4 and Soyuz 20. Izvestiya (USSR), Dec. 5, 1975, p. 7.

[373] Salyut 4/Soyuz 20 flight continues as planned. Moscow, TASS (in English), Dec. 4, 1975.

[374] Pliskovskiy, G. N. et al. Determination of ammonia in the atmosphere of a biosatellite mockup and an approach to setting standards. Space Biology and Aerospace Medicine (USSR), No. 2, 1975, 27–32 (FRD #2336).

experimentation is an important adjunct to the manned spaceflight effort which merits continued support in the future.[375]

B. EXOBIOLOGY

The Soviet Union and the United States support a research effort to search for lower life forms on other planets of the solar system and in the universe at large. This research is referred to as extraterrestrial biology or exobiology. Much of the work involves studies of the organic and inorganic origins of life on Earth. By better understanding how life evolved on Earth, it is felt that the probability of life having evolved on other celestial bodies can better be determined. Therefore, many studies classified as "exobiology" are really involved in detailed studies of the organic and inorganic chemistry of terrestrial substances as they might have played a role in initial, primordial life processes. Other studies involve subjecting simple terrestrial life forms such as bacteria and viruses to conditions simulating environmental conditions on other solar bodies such as Venus, Mars, and the Earth's moon.

A large amount of literature either directly or indirectly concerned with exobiology has been generated. The prominent Soviet researcher in the field, A. I. Oparin, cited 673 references in his recent review of the subject. Exobiology research is subdivided into the following categories:

- Origin of carbon compounds and their evolution in the Universe;
- Evolution of carbon compounds in the solar system;
- Evolution of organic substances on the Earth;
- Models of abiogenic (non-biological) and biogenic synthesis of life on primitive Earth;
- Models of various systems of compounds and energy as precursors of life;
- Dynamics and molecular genetics of living systems;
- The role of light, heat, and other energies in the formation of life;
- Methods of detecting extraterrestrial life; and
- Automated biological laboratories for exobiological investigation.[376, 377]

Thus far, there continues to be considerable controversy about theories involving the origins of life on Earth and there have been several changes in theory in the past 50 years. With regard to the abiogenic synthesis of organic matter on Earth, radioastronomic data has indicated that complex carbon compounds exist elsewhere in space. Some Russian specialists therefore hypothesize that during its early evolution, Earth captured a large amount of organic matter from space which ultimately led to the evolution of life. With regard to pathways of the evolution of life, the same Russian specialists hold that evolution did not proceed in an orderly fashion along one par-

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[375] Parfenov, G. P. et al. Results and prospects of microbiological experiments in outer space. Space Life Sciences. Vol. 4, 1973, 160–179.
[376] Oparin, A. I. Theoretical and experimental prerequisites for exobiology. In: Foundations of Space Biology and Medicine. Vol. 1, Ch. 2, Part 3. Washington, D.C., NASA, 1975 (in press).
[377] Rubin, A. B. Search for and investigation of extraterrestrial forms of life. In: Ibid, Vol. 1, Ch. 3, Part 3.

ticular line, but life arose in several parts of the Earth simultaneously. The "primordial broth" theory, whereby life evolved from highly concentrated organic matter, is therefore rejected. It is speculated instead that the early precursors of life evolved from a water solution containing complex molecules. These complex systems then became subject to natural selection which eventually led to specialization and ultimately, the transition from chemical to biological evolution. The controversy about the mechanism of the evolution of life continues to be the subject of international seminars and conferences on the subject. The Russian specialist, A. I. Oparin, has recently concluded that, whereas the basic concepts of life's origin on Earth have fundamentally changed little in the last half century, some individual stages in that process are now perceived differently. Oparin and others have been somewhat successful in simulating the formation and organization of precursory substances to life under laboratory conditions.[378-380]

Thus far, there is no hard evidence that life exists either in the solar system or the universe in general, although it is a popular theory that conditions for life, if not life itself, may exist on many thousands of planets, and even moons of planets, throughout the universe. There is therefore considerable concern that: 1) manned or unmanned spacecraft from Earth could introduce (contaminate) life on another celestial body; 2) a spacecraft returning from another celestial body could contaminate Earth with a form of extraterrestrial life. The sterilization of spacecraft has therefore been a topic of considerable international discussion in recent years. American specialists recommend that pharmaceutical devices and materials bound for extraterrestrial targets be sterilized with dry heat for two hours at 170 degrees centigrade (100 degrees centigrade is the boiling point of water at the Earth's surface). It is official Soviet policy that the same materials be heated in a chamber for one hour at 160–170 degrees.[381]

The sterilization of entire spacecraft systems is a complicated problem for which there is no unanimous international policy. In the final process, the American Viking spacecraft (bound for Mars) was sterilized in a very dry atmosphere at a temperature close to 112 degrees centigrade for 40 hours. But prior to the final process, individual components were sterilized by various means according to their heat or other physical tolerances before assembly in a sterile chamber. Similarly, the official Soviet policy for spacecraft sterilization has never been made specific in the literature. It is believed that individual spacecraft components are sterilized by different methods (heat, ionizing and ultraviolet radiation, exposure to chemicals etc.) before final assembly in a sterile chamber. The final sterilization process is believed to involve exposure of the entire spacecraft assembly to a mixture of ethylene oxide and methyl bromide. The spacecraft is then encapsulated hermetically and released in space after launch. Since it is recognized internationally that complete sterilization of a spacecraft

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[378] Oparin, A. I. et al. Current concepts of the means of the origin of life. In: Reports of the 4th International Biophysical Congress. Vol. 4, Part 2, 1975, pp. 685–698 (FRD #2322).

[379] Oparin, A. I. Evolution of concepts on the origin of life: 1924–1974. Izvestiya of the Academy of Sciences, USSR. Biological Series. No. 1, 1975, 5–10 (FRD #2210).

[380] International Seminar: "The Origin of Life". Ibid. 160–163 (FRD #2209).

[381] Imshenetskiy, A. A. et al. Extraterrestrial Life and Its Detection Methods. Moscow, "Nauka" Press, 1970, pp. 230–250 (NASA TT-F-710).

is not possible, a spacecraft is considered to be "sterile" only in the sense that the probability of contamination from the spacecraft on another celestial body is quite low.[382–384]

Another approach in exobiology is the investigation of terrestrial micro-organisms under conditions believed to simulate an extraterrestrial environment. Thus, Soviet and American investigators have subjected a wide variety of lower organisms to artificial atmospheres simulating the environment of Mars. The Soviet "artificial Mars" is a specially designed chamber at the Institute of Microbiology under the U.S.S.R. Academy of Sciences. Some species of xerophytic organisms have survived and multiplied under these extremely harsh conditions of extreme cold, extreme heat, lack of water, and lack of a terrestrial atmosphere. Hence, some Soviet and American specialists believe that there are some areas on Mars where life conceivably could exist. In the opinion of Academician A. A. Imshenetskiy, the study of life on other planets will contribute to a better understanding of the evolution of life on Earth. The first probe to specifically investigate life on Mars is the NASA Viking vehicle which was launched in the summer of 1975 and will land on the surface of Mars in the summer of 1976. This station and a follow-on sister ship will carry out a number of exobiological experiments including the detection and measurement of the metabolism of living organisms, assimilation of carbon monoxide and carbon dioxide; decomposition of substrate; labeling with radioactive carbon; and experiments involving gas exchange. All experiments will be conducted in parallel using data from the same sample. It is not known when the Soviets intend to launch a probe to Mars or other planets.[385–388]

C. THE SEARCH FOR EXTRATERRESTRIAL INTELLIGENT LIFE

While the search for extraterrestrial forms of lower life is limited by the distance biological probes can be dispatched, the search for extraterrestrial intelligence involves the use of radioastronomy and associated electronic equipment with which to detect electromagnetic signals which might indicate that highly developed civilizations exist far beyond the reaches of the solar system. Both the Russians and Americans have developed highly organized individual and collaborative programs for the detection of signals from extraterrestrial civilizations. The collaborative program is exemplified by a conference entitled, "Communication With Extraterrestrial Intelligence (CETI)*, which was held in 1971. Both the Soviets and Americans have radiotelescope systems. A giant Soviet system is located near Pulkovo.

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382 Hall, L. B. (NASA). Personal communication.
383 Imshenetskiy, A. A. Extraterrestrial Life and Its Detection Methods. Op. Cit.
384 The Planetary Quarantine Program: 1956–1973, Washington, D.C., NASA, 1974, 56 p. (NASA SP–4902).
385 Life in the "artificial Mars". Soviet Latviya (USSR). August 7, 1974, p. 2 (FRD #1966).
386 Imshenetskiy, A. A. Space Biology. Successes in Microbiology (USSR), No. 7, 1971, 46–66 (FRD #820).
387 Imshenetsky, A. A. et al. Long term effect of high vacuum on microorganisms. Microbiology (USSR), No. 5, 1973, 836–838 (FRD #1810).
388 Klein, H. P. et al. The Viking, 1975, biological experiments. Icarus, Vol. 16, 1972, p. 139.
* The acronym "CETI" has recently been replaced by "SETI" (Search for Extraterrestrial Intelligence). As a consequence both acronyms are now used interchangeably.

Thus far, the search for extraterrestrial intelligence has not yielded any conclusive data to support the theory that civilizations exist anywhere else in the universe. But the problems of detecting and interpreting signals from such civilizations, if they do exist, are extremely complicated because of the size of the universe, the large number of candidate star and associated planetary systems to be sampled, the element of time, language or mode of communication of other civilizations, and many other physical factors. Research on this subject therefore involves the continuing development of equipment, methodologies, and even philosophies to overcome these formidable barriers.[389-393]

The complexity of the problem of detecting extraterrestrial intelligence is better understood by reviewing the major subcategories of research in the field. These were recently summarized as follows:[394]

Principal Fields of Research on the Problem of Extraterrestrial Civilizations

The problem of extraterrestrial civilizations comprises an intricate complex of topics in philosophy and sociology as well as natural science. Within the domain of this broad interdisciplinary problem a narrower area is to be considered: the CETI problem. This represents a separate task confronting science and technology, including theoretical and experimental work on searching for extraterrestrial civilizations, as well as modeling the basic links in the CETI system. But a successful result will depend on resolving a number of fundamental questions that form the heart of the extraterrestrial-civilization problem.

It is convenient to distinguish two groups of problems for planning the investigations.

GROUP A. FUNDAMENTAL PROBLEMS OF EXTRATERRESTRIAL CIVILIZATIONS INVOLVING COMMUNICATION

1. *Astronomical matters.*—Cosmogony. Discovery of planets, planetlike bodies, and congealed stars. Sky surveys conducted in various parts of the electromagnetic spectrum. Examination of some peculiar sources. Investigation of organic compounds in cosmic objects.

2. *Life.*—A more precise definition of the concept of "life." Possible existence of nonprotein life forms. Origin of life on the earth; possible alternative origins of life on other cosmic bodies, and in interplanetary and interstellar space. Exobiology. Laws of biological evolution and their exobiological generalization.

3. *Intelligence and intelligent systems.*—Refinement of the concept of "intelligence" or "reasoning." Models of an intelligent system. Theory of complex self-organizing systems. Information contacts in complex systems. Symbolic systems; language. Problems in the theories of knowledge and reflection; construction of models.

4. *Mankind.*—Analysis of the laws governing the development of civilization on the earth. Special characteristics of the rise and development of different civilizations worldwide. Forecasting. Development and mastery of the space environment.

5. *Information transfer.*—Optimum methods of communicating information.

These topics are being dealt with independently of the CETI problem itself and therefore are not considered in the present program (except for the sky surveys).

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[389] Shklovskiy, I. S. et al. Space, Life, Intelligence. Moscow, "Nauka" Press, 1973, 334 p.

[390] Sagan, C. et al. Communication with Extraterrestrial Intelligence. Cambridge, Mass., The MIT Press, 1973, 428 p.

[391] Konstantinov, B. P. et al. Inhabited Space. Moscow, "Nauka" Press, 1972, 365 p. (NASA TT–F–820).

[392] Shneour, E. A. et al. (Ed.) Extraterrestrial Life: An Anthology and Bibliography. Washington, D.C., National Academy of Sciences and National Research Council, 1966, 478 p. (Publ. 1296A).

[393] Shklovskiy, I. S. et al. Intelligent Life in the Universe, San Francisco, Holden-Day Inc., 1966, 506 p.

[394] The CETI Program. Astronomy Journal (USSR), No. 5, 1974, 1125–1132 (Soviet Astronomy, 18(5), 1975; translated by the American Institute of Physics).

GROUP B. PROBLEMS PERTAINING DIRECTLY TO CETI

1. Aspects of the theory of cosmic civilizations.

2. Contacts between cosmic civilizations: Possible types of contact and their consequences.

3. Modes of intercourse between cosmic civilizations.—Linguistic media to be devised for establishing information contact between "intelligent" systems.

4. Procedures and scientific-technological basis for seeking signals from extraterrestrial civilizations.—Development of signal search techniques. Influence of the cosmic medium on exchange of signals between civilizations. Choice of optimum electromagnetic wavelength range. Criteria for identifying signals from extraterrestrial civilizations. Characteristics of "call letters." Design of search instrumentation. Modeling of individual links in the CETI system. Computer modeling.

5. Searches for signals from extraterrestrial civilizations.

6. Deciphering of signals.

7. Searches for astro-engineering activity of extraterrestrial civilizations.—Although the main emphasis in this program is given to efforts to find signals in the radio range and to the development of suitable techniques and equipment, a more complete program should also include planning with regard to other aspects of the CETI problem.

In summary, many Soviet and American specialists in extraterrestrial life detection are firmly convinced that simple life and intelligent civilizations most certainly exist in the universe on the basis of strong circumstantial evidence. No conclusive evidence has yet been gathered to support this conviction. To put it mildly, the discovery of extraterrestrial life, to say nothing of extraterrestrial intelligence, would have a most profound impact on all aspects of human life, particularly the space exploration programs of the United States and the Soviet Union.

IX. Conclusions

The Soviet space life sciences support a large and ambitious manned spaceflight and space biology program. In terms of the personnel and facilities involved, the Soviet Union supports the largest and most comprehensive effort in the space life sciences in the world. Qualitatively, the Soviet effort is roughly equivalent to the United States counterpart effort.

There has been a recent trend toward a more open exchange of information and direct collaboration between Soviet and American space life scientists. This trend has been climaxed by a joint manned flight (ASTP), a collaborative biosatellite experiment, the publication of a series of monographs on the space and space life sciences jointly authored by leading Soviet and American specialists, and continued official and private collaboration in international space life sciences conferences and seminars. In the present atmosphere of detente, it seems likely that this trend will continue so that more collaborative efforts in the space life sciences are to be expected in the future.

While the Soviet and American space life sciences efforts are fundamentally similar in emphasis and intent, there are subtle differences in organization, doctrine, and philosophy between the two programs. The differences are most evident in the selection, preparation, and medical maintenance of space crews. But because there continues to be increased collaboration between the two countries in the space sciences in general and in the space life sciences in particular, these differences are expected to be resolved or minimized.

The Soviet effort in the fundamental, space-oriented life sciences appears to be very much larger than its counterpart American effort. Dozens of research facilities and hundreds of highly trained research staff are involved in the Soviet effort, the findings of which are published in a large variety of Soviet scientific periodicals and monographs. From the apparent size of the Soviet effort in this field, it seems likely that the Soviet Union is devoting more of its national resources to manned spaceflight and space biology programs than the United States. This trend continues and there is no indication that a relaxation of emphasis on manned space programs is to be expected.

American successes in manned lunar and orbiting laboratory programs viewed against isolated failures in counterpart Soviet programs has led to some speculation that diminishing Soviet emphasis on this aspect of space exploration and exploitation is to be expected. But continuing statements and commentaries by high Soviet Government officials, academicians, key administrative personnel in the space life sciences, and the extensive Soviet literature being published in this field indicates that quite the opposite is true. Leading Soviet authorities, such as Academician B. N. Petrov of the U.S.S.R. Academy of Sciences continue to publicly predict the development of large, nuclear powered orbiting stations which would house dozens of personnel for many months at a time and be large enough to spin around their axis in order to provide artificial gravity to crew members.[395] Replete in the Soviet space life sciences literature are references to plans for future manned lunar and interplantetary flights.

Recent successes in the Soviet manned spacecraft program, including the recent ASTP flight and the parallel 63 day Soyuz 18/Salyut 4 mission have vindicated the large space life sciences effort. If that effort can be used to gauge the future Soviet intent in space, then the following conclusions would have to be drawn: 1) the size and complexity of upcoming Soviet orbiting space stations will be gradually increased as will the duration of manned missions; 2) the ultimate goal is the manned exploration of the near and far reaches of the solar system and even the space beyond the solar system, technology allowing; and finally, 3) the supporting space life sciences, already large and well supported, seem assured of continued support and growth in the foreseeable future.

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[395] Future space stations. Trud (USSR) Feb. 5, 1975, p. 3 (FRD #2236).

CHAPTER FIVE

SOVIET APPLICATION OF SPACE TO THE ECONOMY

By Lani Hummel Raleigh*

I. Early Recognition of Potential Uses of Applications Satellites

Although Soviet writers early recognized the potential application of satellites to a wide variety of practical uses, including communications relay, direct broadcast, weather observation, navigation and traffic control, study of Earth resources, and development of permanent manned stations in orbit which would perform many tasks, the Russians were initially slow to exploit space. Whereas the first civil applications satellites appeared in the U.S. program in 1958, the year of the first successful American flight, equivalent Soviet flights were delayed until 1966. Thus, despite seemingly advanced space exploitation technology, the Soviets have not moved as rapidly from first flights to operational systems as have the Americans.

II. Communications Satellites

With its vast underdeveloped areas, the Soviet Union benefits greatly from communications satellites. Regions which are remote and difficult to reach are interconnected by satellite without the expense of laying cable through difficult terrain to operate under harsh weather conditions. Through the use of satellites, reliable telephone and television service can be brought inexpensively to all parts of the Soviet Union. In view of such geographic and economic advantages, it is not surprising that the first satellite domestic distribution system in the world was the Soviet Orbita system.

A. Early Experiments

Although space communications in the form of command controls had been tested in many previous Soviet flights, and voice and television circuits were tested as early as 1960 in the Korabl Sputnik series, Kosmos 41 which was launched August 22, 1964, was the first clear precursor of the present Soviet operational communications satellite system.

Kosmos 41 was placed in a parking orbit by a Tyazheliy Sputnik orbital launch platform. A probe rocket was fired to push the payload into an eccentric orbit ranging from a low perigee of 394 kilometers in the southern hemisphere to an apogee of 39,855 kilometers in the northern hemisphere, inclined at 64 degrees to the Equator. It was so synchronized with the rotation of the Earth that it repeated the same

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ground trace each day in its 12-hour orbital period which twice brought it to its high apogee, once over Soviet territory, and once over North America, where it was still visible to Soviet ground stations over the polar region.

At the time, Kosmos 41 was given no special description or publicity. It could not be judged from published sources whether this flight was designed only to test the mechanics of achieving a 12-hour semi-synchronous orbit, and to gather geophysical data, including information on the durability of solar cells in exposure to the space environment at those altitudes; or whether the mission was intended as the first of the Molniya 1 flights, and the communications part of the payload suffered a catastrophic failure. However, as soon as the orbital elements were published, Western observers were able to identify its most likely mission as being associated with plans for a communications satellite. This was confirmed in 1969.[1]

B. THE MOLNIYA SYSTEM

The first Molniya 1 satellite was launched on April 23, 1965, in a flight nearly parallel to that performed by Kosmos 41 the previous year. Molniya 1 was described as having the main task of relaying television programs, long distance bilateral, multi-channel telephone, radiophoto, and telegraph communications. Two days after launch, the first trial television broadcast was relayed from Moscow to Vladivostok through Molniya 1. On the 27th of April, a return program was carried from Vladivostok to Moscow for further distribution by land line to all the Soviet bloc country members of the Intervision system.

Since the initial orbit attained was not precisely 12 hours, the satellite would not repeat the same ground trace. Hence, on May 4, 1965, it was announced that correction engines had been fired to perfect the orbit to that originally hoped for, so that it would not gradually drift to a less desirable relation to Soviet ground stations.

There are now Molniya 2 and Molniya 3 satellites in addition to the Molniya 1 satellites. Molniya 3 provided the first routine color relays and forms the basis of a Washington-Moscow Hotline.

1. Description of Molniya 1

The Molniya 1 is a complex craft somewhat similar to the early lunar and planetary craft. The main body is a pressurized cylinder with conical ends and external cooling/heating coils, related to the temperature regulating system, which are wrapped around the main cylinder. There are also small correcting rockets to maintain the attitude of the spacecraft in the required position. Atop the main cylindrical body are the special correction motor system and Sun-seeking optical sensors. This subsystem is conical in shape and is surrounded by a ring of gas bottles containing fuel for the correction system. At the opposite end of the main body are Earth-seeking optical sensors. Extending from either side of the main body are the structures for two high-gain antenna systems, steerable parabolic dishes used for the main communications tasks. Also, at the bottom of the main body are six fairly long panels which fold outward to radiate from the main body like petals on a daisy. These are covered with solar cells

[1] Pravda, Moscow, Sept. 24, 1969, p. 3.

to power the craft. They generate 500–700 watts over a long period of time.

Inside the craft are the main communications receivers and transmitters, the buffer batteries, various sensors and telemetry systems, an on-board computer, and other necessary equipment for housekeeping and control.

The directional parabolic antennas have a gain of approximately 18 db. According to Soviet account, the Molniya 1 Sun sensor locks onto the Sun to maximize the power for the solar cell system; and, there is a gyrostabilizer to maintain this attitude. The Earth seekers then lock onto Earth and are used to point the parabolic antennas to maximize signal strength. The ground stations on Earth also track the satellite and point their own antennas directly at the satellite. The two antennas are not used simultaneously. The second antenna is supplied for redundancy to extend useful life.[2]

2. Operation of Molniya 1

The communications equipment of the satellite includes three complete transceiver systems, one active, and two as standby in the interest of redundancy to extend operational life. Most of the equipment is solid state except for metal-ceramic triodes, klystrons, magnetrons and travelling wave tubes. The useful life of the tubes is 40–50 thousand hours. Although in the first models the input noise level is 2000–3000° K, tunnel diodes were soon to reduce this by a factor of 2 to 3. There are four travelling wave tubes used, three active, and one as a spare. Television service is provided in a frequency range from 3,400 to 4,100 MHz, and other telecommunications in a frequency range of 800 to 1,000 MHz. Television is transmitted at a power level of 40 watts, and data and telephony at 20 watts.

The capability of the payload includes a complete television channel with additional capability for television audio, multichannel telephony, VHF telegraphy (by multiplexing some of the telephone channels), and photofacsimile.[3]

By flying the eccentric orbit chosen, the Molniya 1 has unique advantages for the Soviet Union. The orbit is easier to attain than a 24-hour synchronous orbit. Since the energy requirements in propulsion are less, a heavier payload may be used. In contrast to the equatorial orbits used by the United States, the inclination of orbit (63°–66°) places the apogee in a very favorable relation to the generally northern location of the Soviet Union. And, there is less ground interference at high look angles than would be true with an equatorial orbit viewed from the Arctic.

Because the first U.S. communications satellites were placed in low orbits, they required active tracking. Each satellite provided limited time coverage, so that many were required for continuous coverage. The number of satellites presented a complicated "handover" problem, often with two antennas required at each ground station. In view of these difficulties, the United States very quickly shifted to the 24-hour synchronous type of operation, once Syncom proved that such orbits could be attained at reasonable cost.

[2] Aviatsiya i Kosmonavtika, No. 7, 1968, pp. 17–20.
[3] Idem.

The Soviet system does not have the difficulties which characterized the earlier American system. Although the Soviet system requires active ground tracking with mobile antennas, the orbit chosen for Molniya 1 is so high that the movement of the ground station antenna is fairly slow. And, approximately 8 hours of useful coverage of the Soviet Union is provided from a single pass of the satellite over Soviet territory and its environs.

The United States began its communications satellite program with a small satellite and a few expensive ground stations and progressed toward satellites of much greater capacity and power. In contrast, from its inception the Soviet system has utilized a fairly large and heavy satellite with a high power output. The Russians have thus been able to economize on the size and cost of their large number of ground stations.

Some U.S. analysts have speculated that the Molniya 1 communications satellites have been shifted to a government role, particularly if not exclusively military. This deduction is based on the fact that Molniya 1 launches have continued despite the initiation of the Molniya 2 and 3 launches.[4]

3. Molniya 2

On November 24, 1971, the U.S.S.R. launched its first Molniya 2 communications satellite. The same launch vehicle was used for the Molniya 1 launch so it may be presumed that there is no great increase in the size and weight of the satellite and that the main improvement lies in the electronics. Solar panels have been increased, adding about 50 percent to the power. With the change to higher frequencies, the earlier umbrella-like antennas have disappeared.

The Molniya 2 announcements mention "international cooperation", a phrase absent from standard Molniya 1 announcements. This fact, along with the use of higher frequencies (6.087 GHz), may suggest a move towards compatibility with the Intelsat system.[5]

The appearance of Molniya 2 did not displace the Molniya 1 satellites which continue to be launched. Originally, Molniya satellites were flown in groups of three, in orbits separated by 120°. At present they are flown as 4 triplets (each triplet consisting of one Molniya 1, one Molniya 2, and one Molniya 3 satellite) in orbits separated by 90°.[6]

4. Molniya 3

The first Molniya 3 was launched on November 2, 1974. The principal difference between Molniya 3 and the earlier Molniya satellites seems to be its color television relay and higher communications frequencies. Previous Molniyas have broadcast mainly black and white television with numerous experimental color programs.

5. Launch Programs of Molniya 1, Molniya 2, and Molniya 3

There follows a brief table of Molniya launches, together with a few Kosmos launches with the same characteristics, which represented either test flights, Molniya failures, or military communications satellites outside the Molniya program but using essentially the same hardware.

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[4] Aerospace Daily, September 8, 1975, p. 33.
[5] Flight International, February 8, 1973, p. 206a.
[6] Flight International, December 19, 1974, p. 880, plus current observations.

TABLE 5-1—LIST OF SOVIET COMMUNICATIONS-RELATED SPACE FLIGHTS

Satellite	Initial Orbital Elements: Period (min)	Apogee (km)	Perigee (km)	Launch Date
Kosmos 41	715	39,855	394	Aug. 22, 1967
Molniya 1-1	720	39,957	548	Apr. 23, 1967
Molniya 1-2	719	40,000	500	Oct. 13, 1968
Molniya 1-3	710	39,500	499	Apr. 25, 1964
Molniya 1-4	713	39,700	485	Oct. 20, 1965
Molniya 1-5	715	39,810	460	May 24, 1965
Kosmos 174	715	39,750	500	Aug. 31, 1966
Molniya 1-6	712	39,600	465	Oct. 3, 1966
Molniya 1-7	714	39,740	456	Oct. 22, 1967
Molniya 1-8	713	39,700	460	Apr. 21, 1967
Molniya 1-9	715	39,770	470	July 6, 1968
Molniya 1-10	712	39,600	490	Oct. 5, 1968
Kosmos 260	712	39,600	500	Dec. 16, 1968
Molniya 1-11	713	39,700	470	Apr. 11, 1969
Molniya 1-12	711	39,540	520	July 22, 1969
Molniya 1-13	703	39,175	487	Feb. 19, 1970
Molniya 1-14	705	39,280	470	June 26, 1970
Molniya 1-15	706	39,300	480	Sept. 29, 1970
Molniya 1-16	707	39,430	435	Nov. 27, 1970
Molniya 1-17	712	39,600	480	Dec. 25, 1970
Molniya 1-18	705	39,300	470	July 28, 1971
Molniya 2-1	706	39,350	460	Nov. 24, 1971
Molniya 1-19	703	39,200	490	Dec. 20, 1971
Molniya 1-20	695	39,260	480	Apr. 4, 1972
Molniya 2-2	705	39,300	460	May 19, 1972
Molniya 2-3	703	39,200	480	Sept. 30, 1972
Molniya 1-21	705	39,300	480	Oct. 17, 1972
Molniya 1-22	703	39,100	500	Dec. 2, 1972
Molniya 2-4	705	39,300	470	Dec. 12, 1972
Molniya 1-23	703	39,200	470	Feb. 3, 1973
Molniya 2-5	702	39,100	500	Apr. 5, 1973
Molniya 2-6	705	39,280	480	July 11, 1973
Molniya 1-24	679	37,970	480	Aug. 30, 1973
Molniya 2-7	736	40,600	630	Oct. 19, 1973
Molniya 1-25	702	39,140	480	Nov. 14, 1973
Molniya 1-26	737	40,900	460	Nov. 30, 1973
Molniya 2-8	737	40,865	466	Dec. 25, 1973
Kosmos 637	1,426	35,600	35,600	Mar. 26, 1974
Molniya 1-27	738	40,713	646	Apr. 20, 1974
Molniya 2-9	737	40,850	463	Apr. 26, 1974
Molniya 2-10	737	40,900	460	July 23, 1974
Molniya 1-S-1	1,439	35,850	35,850	July 29, 1974
Molniya 1-28	736	40,617	683	Oct. 24, 1974
Molniya 3-1	732	40,690	650	Nov. 21, 1974
Molniya 2-11	737	40,675	641	Dec. 21, 1974
Molniya 2-12	737	40,685	640	Feb. 6, 1975
Molniya 3-2	736	40,660	636	Apr. 14, 1975
Molniya 1-29	737	40,848	468	Apr. 29, 1975
Molniya 1-30	737	40,890	450	June 5, 1975
Molniya 2-13	737	40,864	455	July 8, 1975
Molniya 1-31	737	40,681	639	Sept. 2, 1975
Molniya 2-14	736	40,836	470	Sept. 9, 1975
Kosmos 775	1,442	35,900	35,900	Oct. 8, 1975
Molniya 3-3	736	40,930	470	Nov. 14, 1975
Molniya 2-15	736	40,836	451	Dec. 17, 1975
Statsionar-1 (Raduga-1)	1,434	35,800	35,800	Dec. 22, 1975
Molniya 3-4	736	40,800	470	Dec. 27, 1975

SOURCE: Appendix A.

6. The Orbita Ground Station System

Orbita is the name used to describe the total complex of ground stations used in conjunction with the Molniya satellites. Each can receive television transmission relayed through the Molniya satellites, with further relay to the surrounding area. Additionally, the Orbita stations can receive and transmit telephone, telegraph, facsimile, and weather data via the Molniya satellites.

The first year of operation was limited to tests between Moscow and Vladivostok of the several types of service possible through the system. By 1966, the first phase of installation of Orbita stations was com-

pleted to make the service more widespread. Each later year has brought an additional increment of ground stations. A special effort was made to have the Orbita system operational over much of the country by the fall of 1967 to carry the celebrations of the 50th anniversary of the U.S.S.R. On November 2, 1967, operations opened to 23 points for regular service to 100 million persons.[7] Another concentrated effort to add stations in more remote regions of the Arctic and Eastern Siberia was made before the celebration of the 100th anniversary of Lenin's birth on April 22, 1970.

(*a*) *Station Construction.*—Orbita stations are circular and constructed of reinforced concrete. Each station serves as the foundation for the 12-meter diameter parabolic reflecting antenna. A central hall under the antenna houses the receiving equipment, the antenna aiming apparatus, and the switchboard which transfers the signal to local land lines after the signal has been converted from the space transmission mode.[8]

Separate compartments and rooms located around the outside of the central hall contain the air conditioning and cooling equipment for the entire apparatus and the automatic control system for the antenna-aiming equipment. An extra equipment block is necessary to separate the audio and video signal components.[9]

(*b*) *Orbita Station Locations.*—When the first phase of Orbita station location was complete in November 1967, there were two-way transmission stations at Moscow and Vladivostok as well as receiving stations at Murmansk, Arkhangelsk, Syktyvkar, Ashkhabad, Frunze, Alma-Ata, Novosibirsk, Surgut, Vorkuta, Kemerovo, Norilsk, Krasnoyarsk, Bratsk, Irkutsk, Ulan-Ude, Chita, Yakutsk, Magadan, Komsomolsk, Yuzhno-Sakhalinsk, Khabarovsk, Petropavlovsk-Kamchatka. By 1975 stations which were either completed or under construction included those at Gur'yev, Abakan, Kyzyl, Dzhezkazgan, Bilibino, Nikolayevsk-na-Amure, Aldan, Pevek, Sangar, Tazovskiy, Anadyr, Nar'yan-Mar, Skovorodino, Nadym, Ust'Ilimsk, Dushanbe, Khorog, Yuzhno-Kuril'sk, and the television center located in Tadzhikistan in the Pamir mountains. Plans for new stations include Aleksandrovsk and Poronaysk. The general target is to add six to eight stations a year, so that by 1980, virtually all of the Soviet Union will have television service.[10] According to the Russians there are presently 56 Orbita stations. The Soviet plan calls for 60 operating stations by the end of 1975.[11]

Orbita stations outside the borders of the Soviet Union include those at Ulan Bator in the Mongolian Peoples Republic, at Haruco, Cuba, seventeen miles from Havana, and at Prague, Czechoslovakia.

(*c*) *Operation of Orbita Stations.*—The operation of each of the Orbita stations is similar. The two-mirror parabolic dish antenna has a low noise temperature of 30–40 degrees Kelvin (including the waveguide run), and a low level of side lobes. The antennas have a high surface utilization with a focal length of 3 meters. The effective noise temperature of the entire receiver unit is 60–70 degrees Kelvin.

[7] Moscow Radio, October 26, 1967, 1900 GMT.
[8] Pravda, Moscow, October 29, 1967, p. 3.
[9] Idem.
[10] Aviatsiya i Kosmonavtika, No. 5, 1970, pp. 12–13; Vestnik Suyazi No. 4, April 1970, p. 29.
[11] Moscow Radio, May 7, 1975, 0100 GMT; An Audience of Millions, Izvestiya, Moscow, May 7, 1974, p. 6.

The signals from the antenna are fed through the wave-guide to the band-pass filter, through two low-noise parametric amplifiers, which increase signal strength 100 million times, and then on to the rest of the receiving terminal equipment. The first parametric amplifier is cooled by liquid nitrogen and operates without frequency conversion. The second parametric amplifier is not cooled and operates with a double frequency conversion. For operating convenience, even at the cost of some noise, all the receiving equipment is located in the same chamber. The equipment is mounted on a standard bay with an IF filter and preamplifier, as well as quartz crystal heterodyne oscillator with a frequency multiplier and an additional IF filter which prevents overload of the amplifiers by locally generated noise. A tunable beat frequency oscillator is included to provide for manual tuning of the signal in addition to automatic tuning provided by the quartz crystal heterodyne oscillator with a frequency multiplier.[12]

The quality of the television picture output from the ground stations in most respects is fully adequate by international standards. The scanning standard is 625 lines/frame, 25 frames/second with audio integral to the video band on a PCM basis. The signal is transmitted from the Orbita ground station to the local broadcast television station by a single hop, point-to-point microwave or coaxial cable link. Further improvements in the Orbita stations have been adding the capability of sending and receiving radio telephone and facsimile signals between the station and six Molniya satellites. Still other equipment being added to Orbita stations will greatly expand their capacity to provide the complete range of telecommunications activity, including computer data relay.[13]

C. THE SYNCHRONOUS COMMUNICATIONS SATELLITES

1. Kosmos 637, Molniya 1–S, and Kosmos 775

On March 26, 1974, the U.S.S.R. launched its first 24-hour synchronous satellite—Kosmos 637. The satellite was probably designed to study problems of launch and stabilization.

The Russians launched their first synchronous orbit communications satellite—Molniya 1–S—on July 29, 1974. The spacecraft was placed in an equatorial orbit, 35,850 kilometers high with a period of 23 hours 59 minutes and an inclination of 0 degrees 4 minutes. The equatorial orbit was chosen in order to give coverage to Eurasia, Africa, and Australia. Molniya 1–S is probably a prototype for the Statsionar communications satellite. Statsionar satellites would be used in an international consortium known as Intersputnik (see below).

On October 8, 1975 the Russians launched their third synchronous orbit satellite, Kosmos 775. It has been suggested that Kosmos 775 could also be a precursor to the Statsionar; however, its mission has not been positively identified.

2. Statsionar/Raduga

According to notifications submitted by the U.S.S.R. to the International Frequency Board of the International Telecommunications

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[12] Pravda, Moscow, October 29, 1967, p. 3; Radio Moscow, No. 10, pp. 16–17; Elektrosvyaz', No. 11.

[13] Radio Moscow, No. 10, October 1967, pp. 15–16. This source discusses more technical aspects of the circuits than is presented here. See also Elektrosvyaz' No. 11, 1967, pp. 4–8.

Union, the Soviet Union plans to launch three geostationary communications satellites over the Indian Ocean during 1975–76, primarily for coverage of the U.S.S.R. and Eastern European countries. Notification for Statsionar–T was published June 9; notifications for Statsionars 2 and 3 were published September 9.

Statsionar–T is intended for television broadcasting within the territory of the Soviet Union. A station located at Gus-Khrustalniyi, near Moscow, will transmit to a network of community-reception Earth terminals situated in the eastern regions beyond the Urals, in Siberia and the extreme north of the U.S.S.R. Statsionar–T will be placed in an orbit at 99 degrees East Longitude. Earth-to-space uplink will be 6.2 GHz $\pm$12 MHz. Downlink will be 714 MHz $\pm$12 MHz.

Statsionar 2 will provide communications services to Europe and the western portion of the U.S.S.R. It is designed for telephone, telegraph, and phototelegraph communications and for sound broadcasting and television program transmissions. The satellite will be placed over eastern Africa at 35 degrees East Longitude. Earth-to-space uplink will be 5.75–6.2 GHz. Downlink will be 3.42–3.87 GHz.

Statsionar 3 will be essentially identical to Statsionar 2. It will function in the same frequency bands and have the same technical characteristics. However, Statsionar 3 will serve the U.S.S.R. exclusively except for the extreme north and Kamchatka, a peninsula north of Japan. The satellite will be located at 85 degrees East Longitude.[14]

Later, the Russians disclosed plans to launch a global satellite communications system consisting of seven geostationary Statsionar spacecraft positioned over the Indian, Pacific, and Atlantic Oceans. The Statsionar system would operate in the 4–6 GHz bands and would duplicate the coverage of the global system of the 91-nation International Telecommunications Satellite Organization. The major difference between the two systems is the type of Earth terminal used. The Statsionar satellites would operate with smaller and cheaper Earth terminals, equipped with 30-foot (9-meter) diameter antennas, and the standard antennas operating with the Intelsat space segment are 90–100 feet (27–30 meters) in diameter.

Statsionar 4 is planned for launch in 1978–79. Its coverage would extend from the Mideast and the U.S.S.R. to the eastern half of the United States and Canada in the Northern Hemisphere and would include all of Africa and South America in the Southern Hemisphere. The satellite would be stationed at 14 degrees West Longitude. The frequency range of Statsionar 4 for the Earth-to-space uplink is 6–6.25 GHz. The downlink is 3.6–3.9 GHz.

The planned position for Statsionar 5 is at 58 degrees East Longitude over the Indian Ocean. It would have a potential coverage of most of the Soviet Union, that portion of Europe not covered by Statsionar 4, the Mideast and Africa. Statsionar 5 is scheduled for launch in 1978–79. Its uplink frequency would be from 6–6.25 GHz. Downlink would be from 3.67–3.9 GHz.

Statsionar 6 will be positioned at 85 degrees East Longitude over the Indian Ocean. The satellite will have two transmit antennas, both concentrating coverage in the Northern Hemisphere. According to Soviet plans, one of the antennas will cover most of Europe, the west-

[14] Aviation Week and Space Technology, New York, September 22, 1975, p. 17.

ern half of the U.S.S.R. and the northern segment of the Mideast. The second antenna will expand transmit coverage to the northern half of Africa and the eastern U.S.S.R. Reception capability would include signals from Earth terminals in the Southern as well as the Northern Hemisphere. The areas of reception capability would include approximately one third of the Earth's surface, from near the north and south polar regions through central Africa on the west and Australia on the east.

The planned position of Statsionar 7 is at 140 degrees East Longitude over the Pacific Ocean. It will transmit to the eastern area of the U.S.S.R. and areas southward in the Northern Hemisphere, but the reception antenna will extend this coverage area into the Southern Hemisphere to near the south polar region.

Statsionar 8, scheduled for launch in 1980, is supposed to be positioned at 25 degrees West Longitude over the Atlantic, and will cover an area in the Northern Hemisphere extending from the eastern portion of the U.S.S.R. to mid-Canada and the United States. The uplink frequency band would be from 5.75–6 GHz. The downlink frequencies would be from 3.42–3.67 GHz.

Statsionar 9 is supposed to provide Northern Hemisphere coverage of most of the U.S.S.R., Europe, Africa and the Mideast. It is scheduled for launch in 1980 and will be positioned at 45 degrees East Longitude over the Indian Ocean.

Statsionar 10, which is also planned for 1980 launch, will be positioned at 170 degrees West Longitude to provide transpacific coverage.[15]

Reportedly, from the U.S.S.R. notification on the Statsionar system it is evident that there is a possibility of frequency interference problems with the Franco-German Symphonie satellite now operating over the Atlantic and the two satellites Indonesia plans for its domestic system, scheduled to become operational in 1976, as well as several Intelsat satellites. Thus, the problem of radio frequencies will have to be resolved before the full Statsionar system becomes operational.[16]

On December 22, 1975 the Russians announced the launch of a new stationary communications satellite named "Raduga" (rainbow). It is assumed that Raduga is another name for the first satellite launched in the Soviet Statsionar series. It has also been speculated, but not confirmed, that Raduga or Statsionar-1 is in fact the same Statsionar-T satellite referred to earlier.

D. BROADER PROPOSALS AND APPLICATIONS OF SOVIET COMMUNICATIONS SATELLITES

1. *International Links*

(*a*) *Intersputnik System.*—At the 1968 United Nations-sponsored meeting on the peaceful uses of outer space, the Russians unveiled their plans for an international consortium known as Intersputnik which would rival the Intelsat system in providing communications services. At Vienna the Russians discussed their future plans for Intersputnik which included progressing from the Molniya satellites to an advanced 24-hour synchronous system. The Russians did not discuss technical details but said that the satellite's operation would be compatible with

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[15] Aviation Week and Space Technology, New York, December 15, 1975, p. 16.
[16] Ibid., p. 15.

the Intelsat system and that the satellite would be quite large and have a high power output.[17]

On November 15, 1971, nine countries signed an agreement in Moscow to establish the Intersputnik system. Parties to the agreement are: Bulgaria, Cuba, Czechoslovakia, East Germany, Hungary, Mongolia, Poland, and Romania.

The first direct television transmission from the U.S.S.R. to Cuba was performed November 7, 1973 with the telecast of the Red Square Parade. Later, telecasts of Soviet Communist Party Secretary Leonid Brezhnev's state visit to Cuba were relayed to Moscow. The Intersputnik system was formally inaugurated in February 1974 with the commencement of regular relays, via Molniya 2 satellite, between Cuba and Russia. Telecasts were relayed by the Caribe Earth station, equipped with a 12 meter dish antenna and located 30 kilometers from Havana in Haruco. Later, a Czechoslovakian station in Prague was completed on the eve of the 1974 May Day celebrations, and, an Ulan-Bator, Mongolia station was finished before the October celebrations of the same year.

(b) *U.S.-U.S.S.R. Cooperation.*—The Soviet Union has constructed a major Earth terminal close to L'vov in the Ukraine near the Polish border to operate in international commercial communications with Intelsat. The Russians have purchased from ITT Space Communications (International Telephone and Telegraph Corporation) twelve duplex voice-grade channels of Spade terminal equipment that makes possible operation with satellites on a demand-assignment basis. ITT-U.S.S.R. negotiations on the Spade equipment developed during the Washington-Moscow hotline discussions (see below). With Spade terminal equipment, the communicator can utilize satellite channels that may remain unused for long periods. Spade equipment installed at the L'vov station would give the U.S.S.R. direct access on a demand assignment basis to 25 similarly equipped stations in the United States, Canada, Peru, Brazil, Argentina, United Kingdom, Netherlands, France, Italy, Greece, Switzerland, West Germany, and Sweden.[18]

(c) *Washington-Moscow Hotline.*—The United States and U.S.S.R. on September 30, 1971 signed accords on the prevention of accidental warfare which authorized the establishment of a new Washington-Moscow "hotline" via satellite. The main objective of a satellite link would be increased reliability. Although the terrestrial hotline, which was established as a result of the Cuban missile crisis, has never been a target of planned sabotage, it has been subject to occasional disruption, with sections of the cable blacked out by fire, pilfered, and once plowed by a Finnish farmer.

The hotline system consists of two duplex telephone-bandwidth circuits equipped for secondary telegraphic multiplexing and four ground stations for transmission and reception. One circuit is on the Molniya system and the other is on the Intelsat system. Encoded teletype messages will go from the United States to Moscow in English via the Intelsat system and from Moscow to the United States in Russian via Molniya 3 satellites.

Originally, the Russians intended to use a station in the suburbs of Moscow for Intelsat and a Molniya station at Vladimir. However,

[17] Aviation Week and Space Technology, New York, August 26, 1968, p. 19–20.
[18] Aviation Week and Space Technology, New York, September 22, 1975, p. 9.

because of severe winter weather conditions in the Soviet Union, the Russians have constructed a second Intelsat station, approximately 50 miles from L'vov, to ensure increased dependability.[18a] The United States has a Molniya station at Fort Detrick in Frederick, Maryland, and an Intelsat station at Etam, West Virginia.

Although Soviet and American communications experts have successfully tested the new network, the system is not scheduled to begin operation until the second half of 1976. The actual operation of the system awaits the launch of a fourth functioning Molniya 3 satellite.[18b]

(*d*) *"Mars" Portable Ground Station.*—The Soviet "Mars" portable ground station for the Molniya communications satellite system was first used in November 1973 to transmit television broadcasts to the Soviet Union of Breshnev's visit to India. The Mars station was also used in Ulan Bator during the festivities for the 50th anniversary of the Mongolian Peoples Republic to transmit television programs between the Soviet and Mongolian capitals. It has also relayed television signals from Havana and Sofia.

The air-transportable, truck-mounted unit has a 7-meter dish antenna and contains essentially the same elements as the orbital permanent ground stations for Molniya. The large power output of the Molniya satellites makes the use of this small transportable station possible. Mars, which can be moved from point to point while semi-deployed, has a capacity of one color television image and one audio channel. A distinctive feature of the portable station is its capability to operate with satellites which are either in an elliptical or geostationary orbit.

2. Joint Experiments with France

Like much of the rest of the world, the Soviet Union has not only had a rapid expansion of television services, but has moved toward use of color broadcasts, although not at so fast a pace as the United States and Japan. After studying various technical alternatives to the achievement of color, the Soviet authorities selected the French SECAM 3 system, which they now build under license.

The Russians have also demonstrated color television exchanges with France via Molniya 1, using the main ground station at Moscow, while the French used their Intelsat station at Pleumeur Bodou in France. By this means, the video portion of a color program was sent on November 29, 1965 from Moscow to Paris. A return broadcast was made from Paris to Moscow on May 28, 1966. There followed thirteen days of additional tests in both directions.

In 1966, when General DeGaulle visited Moscow, Molniya 1 was used not only to broadcast the program to Soviet outlets, but also was relayed to Paris.

E. FUTURE OF COMMUNICATIONS SATELLITES—TECHNICAL CONSIDERATIONS AND DIRECT BROADCAST SATELLITES

Soviet radio engineers and communications specialists are studying the optimum relationship between the power of on-board transmitters and the scale of the equipment at ground stations for the

[18a] Undated State Department Press Release issued by the Direct Communications Link (DCL) Delegation.

[18b] "Soviet and the U.S. Are Shifting Hot Line to Satellite Systems," Christopher Wren, New York Times, March 23, 1976.

reception of information. The greater the power of the on-board transmitter, the simpler are the ground antennas and the receiving equipment. However, this is compensated for by a complication of the satellite and an increase in its weight. Thus the question of alternative communication distribution systems arises. One alternative is the use of one relatively large antenna along with ground channels as is done in the Orbita system. Another alternative is the use of a more powerful satellite with receivers in each populated place similar to the Indian approach. Both these directions are technically feasible.[19]

Eventually, the power of the on-board transmitters could be increased to sufficient strength for direct television broadcasting from space. However, Soviet views on direct broadcasting from space are ambivalent. They have referred to such plans as means of aggression. They reason that such programming might involve the spread of hostile propaganda and would circumvent the carefully controlled programming now under the jurisdiction of the individual states. These fears inspired a Soviet-sponsored proposal on direct broadcast television satellites which would authorize any receiving nation to destroy or jam the satellite if it judged the broadcast illegal or erroneous. In the draft treaty presented to the United Nations by Foreign Minister Andrey Gromyko on October 12, 1972 specific illegal areas would include those that: were detrimental to the maintenance of international peace and security; interfered in intrastate conflicts; encroached on fundamental human rights; presented violent, horror-oriented, pornographic and drug propaganda; were against the foundations of local civilization, culture, mores or traditions; or presented misinformation. The sole judge of the illegality would be the receiver nation.[20]

At the same time the Russians have discussed in glittering generalities the vast potential of direct broadcast from satellites. According to academician Boris Petrov:

> Thanks to . . . direct transmissions of television programmes through sputniks to conventional television aerials, it will be possible to have a wider dissemination of scientific, medical and health and agricultural knowledge. Space television will become available to the population even in the most remote parts of the world.[21]

And, more recently, Oleg Belotserkovets, rector of the Moscow Technical Institute of Physics announced:

> Soviet specialists have developed devices which will make it possible in the near future to receive television broadcasts from communications satellites directly through house aerials . . . The quality of the broadcasts will improve . . . when this work is completed there will be practically no places left in the country inaccessible to television reception.[22]

One of these "devices" could be the use of nuclear powered broadcasts. In 1972 it was announced that a nuclear power source was successfully tested in one of the Kosmos satellites. More powerful atomic reactors were to be installed on future sputniks which would enable the satellites to transmit a signal of such strength that reception directly on the television set antenna, without previous reinforcement at the Orbita station, would be possible.[23]

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[19] Konovalov, B., Lightning-Quick Communication, Izvestiya, Moscow, December 31, 1974, p. 5.
[20] Aviation Week and Space Technology, New York, October 23, 1972, p. 20.
[21] Pravda, Moscow, December 30, 1969.
[22] Oleg Belotserkovets, TASS, Moscow, July 1, 1974, 1205 GMT.
[23] Moscow Radio, February 7, 1972, 0930 GMT.

III. Meteorological Satellites

Weather reporting by satellite was another of the early uses of satellites identified by the Russians, although an operational system was not developed until a much later date. Global weather photos are important for a variety of reasons. First, weather is a total system involving interactions in the atmosphere of the whole planet. Hence, world-wide reporting of phenomena with frequent updatings is important to any forecasting other than immediate forecasting in a particular location. Second, weather distant from the home territory of a country such as the Soviet Union is important to operations of commercial and military aircraft, to the merchant and naval fleets on the seas, and to fishing interests. Former methods never gave adequate or timely coverage because reporting stations were too few and communications were too slow. Satellites have the capacity to provide data needed to remedy these previous shortcomings.

A. EARLY EXPERIMENTS

An earlier section of this study has listed the types of missions assigned to Kosmos satellites, with several of those missions at least indirectly pointed toward development of meteorological satellites. These references included various kinds of solar studies, ionospheric studies, magnetic studies, and studies of the distribution of cloud cover.

1. Kosmos 14 and 23

These two satellites of April 13, 1963 and December 13, 1963 were originally described as conducting miscellaneous geophysical studies. Years later, they were specifically identified as the test beds of electrotechnical systems to guarantee the orientation and stabilization of weather satellites, and as a means for testing power supplies using solar cell batteries.[24] The results of these tests were incorporated in Kosmos 122 and subsequent payloads of that series.

2. Kosmos 45, 65, and 92

These three flights were essentially a part of the military observation recoverable payload series, but it was revealed later that they carried supplemental experiments to aid in the development of weather satellites. They were launched September 13, 1964, April 17, 1965, and October 16, 1965 respectively. Each measured the energy distribution in the Earth's thermal radiation with diffraction-scanning spectrophotometers, and semiconductor bolometers as infrared sensors. Photometric determinations of the cloud cover were made along with measurements of scattered solar ultraviolet radiation. These results, too, were employed in developing Kosmos 122 and subsequent flights of that series.

3. Kosmos 44, 58, 100, and 118

These four flights have never been described as to mission by the Russians, but they flew so nearly the orbit of Kosmos 122 that it must be presumed that they were precursors to the weather satellite series. Either they were to test the basic hardware alone, or they also carried weather cameras for TV and infrared detection, which failed to function. These flights were launched on August 28, 1964, February 26, 1965, December 17, 1965, and May 11, 1966. All four were in circular orbits approximately 640 kilometers in altitude.

[24] Trud, Moscow, January 24, 1968, p. 4.

B. THE ANNOUNCED WEATHER SATELLITES OF THE KOSMOS SERIES

1. Kosmos 122

Kosmos 122 was launched on June 25, 1966, though without an announced specific mission at the time. The Soviet Union and the United States already had an agreement to exchange pictures gathered by weather satellite over the so-called Cold Line between Moscow and Suitland, Maryland. For some months, no satellite data were transmitted over the line because reciprocity was the rule and there were no Soviet pictures forthcoming to match those of the U.S. TIROS series.

However, after some months during which the Russians apparently experimented with this payload, they finally acknowledged that it was a weather satellite.[25] For a few weeks, then, pictures on a selective basis were transmitted to the United States over the Cold Line with reciprocity on the part of this country. The pictures received in the United States by cable were not of good quality, and they arrived too late for real-time use in weather prediction. Part of the trouble lay in the inadequacy of the cable link, but slow Soviet processing in Moscow also seems to have been a factor. The pictures ceased coming after a few weeks, strongly suggesting that the payload instrumentation had had only a short life.[26] This flight was the last one of its series flown from Tyuratam with an A–1 vehicle at a 65 degree inclination.

Although Kosmos 122 was not very successful as a long-term-use operational device, it pioneered some important techniques in weather reporting, more nearly matching in concept the complex U.S. Nimbus series rather than the smaller and simpler original U.S. TIROS type.

(*a*) *Instrumentation.*—Kosmos 122 carried instruments for a television survey of the cloud cover, other cameras for the infrared survey of clouds both by day and night, and further instruments for measuring the radiation of the Earth's atmosphere. The instrumentation of Kosmos 122 made use of the 8–12 micron window of transparency for its day and night scanning of infrared. Ordinary television was used for daytime cloud cover pictures, and for measuring limits of icefields in the absence of clouds. The downward intensity of radiation was measured in three bands. Measurements in the 0.3 to 3 micron range (visible light and lower infrared) made it possible to measure the intensity of reflected radiation, about 70–80 percent from clouds, most of the rest from oceans. Studies in the 8–12 micron band made it possible to estimate the temperature of the Earth or of clouds visible from the satellite. Measurements in the 3 to 30 micron range made it possible to measure the total flux of heat energy from the Earth and from the atmosphere into space. Data from the satellite were processed through a computer on Earth with appropriate allowance for the position of the satellite to derive radiation intensity maps of the Earth. It was made clear that Kosmos 122 was still experimental and reported data for only parts of its total orbit.[27]

(*b*) *Payload Appearance.*—When pictures of Kosmos 122 were released, it was revealed to be a fairly large cylinder, perhaps 1.5 meters in diameter and 5 meters long, and extending from opposite sides were two large solar panels of three segments each. It was three-axis stabilized with fly wheels driven by electric motors; it could tilt

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[25] Izvestiya, Moscow, August 19, 1966, p. 4.
[26] This was confirmed as 4 months by Izvestiya, Moscow, March 17, 1967, p. 5.
[27] Izvestiya, Moscow, August 21, 1966, p. 5.

the panels to collect the maximum amount of solar energy; and it was pointed vertically toward the Earth in order to have its cameras properly aligned. A long arm carried a steerable high-gain parabolic antenna to return data to Earth. A more complete description will be given shortly, as it is apparent that the later operational system uses essentially the same design.

2. Kosmos 144

This was the first launch of a weather satellite from Plesetsk, and came on February 28, 1967. With this launch the Russians began placing the satellites of this configuration in circular 650 kilometer orbits at an inclination of 81 degrees, using the A–1 vehicle. (Today these satellites are placed in an even higher orbit 900 kilometers above the Earth.) Kosmos 144 represents an improvement over Kosmos 122 in that the solar cell arrays are even larger, arranged on four folding panels to a side instead of three. The more extreme inclination of the orbit to the Equator comes closer to giving global coverage than did the 65 degree inclination flights from Tyuratam.

A series of important scientific problems having great significance in the field of space engineering were solved as a result of the development of meteorological satellites. Experience with the continuous operation of Kosmos 144 among others proved that it was possible for solar batteries to operate in a stable manner for long periods of time in outer space under sharply changing temperatures causing thermal "shocks". These "shocks" are experienced when spacecraft pass into shadows and depart from them.[28]

In a number of respects, Kosmos 144 was an advance over its predecessor which had operated only a few months, and then left the Soviet Union with no operating satellite of this type until Kosmos 144 appeared. The newer satellite operated continuously instead of intermittently. The television system was described as having a resolution of several kilometers, for purposes of defining cloud formations. It still left unsolved a Soviet goal of investigating the vertical temperature profile of the atmosphere and other unspecified tasks.

Kosmos 144 was specifically described as equipped with two television cameras, an infrared sensor, a radiation sensor, and a magnetometer. Its picture revealed essentially the same structure as Kosmos 122: a main cylindrical body, with a Sun-sensor at the upper end. On opposite sides were the large four-segment panels covered with solar cells for power supply. At the bottom was a complex smaller cylinder containing the two downward pointing television cameras, the orbital control devices, the radio antennas, the sensors for infrared, magnetic data, and actinometric data. Television camera resolution was described as three times that of the ESSA satellites orbited by the United States. The television cameras switched on automatically any time the Sun was more than five degrees above the horizon. Because Earth illumination varied so much, automatic sensors adjusted the camera apertures to produce high-quality photographs under varied lighting conditions. The picture width of the area covered by each sweep of the satellite was 1,000 kilometers on the surface of the Earth. The infrared equipment performed a scanning motion perpendicular to the flight plane of the satellite, covering a belt 1,100 kilometers in width. The heat radiation detected was converted electronically into signals

[28] Andronov, M., Space Meteorology, Pravda, Moscow, October 26, 1967, p. 3.

proportional to the intensity of the radiated flux and recorded for later playback. In addition to the several scanning instruments, two other wide angle cameras covered the entire disk of the Earth visible from the satellite. On completion of each 96-minute orbit, the entire load of data was dumped to a receiving and processing station in the Soviet Union, clearing the tapes for storing of fresh data from the next orbit.[29]

Kosmos 144 remained in operation for more than a year.[30]

3. Kosmos 156

This satellite was launched on April 27, 1967, and seems to have been a close repeat of the still functioning Kosmos 144, but so timed and phased as to extend the coverage of weather reporting over more hours of the day when operating with its predecessor.

4. Kosmos 184

This satellite was launched on October 24, 1967, possibly because of a deterioration in the quality or even failure of data from Kosmos 156. It had the same characteristics as the others of this group.

5. Kosmos 206

Launched on March 14, 1968, it represented a further continuation of the same series, and may have reflected deterioration in data from Kosmos 184.

6. Kosmos 226

This was the last Kosmos named satellite specifically identified close to the time of launch as an operational weather satellite, and was in the same series as its predecessors. Collectively, all of them were referred to as the experimental phase of the Meteor System.

C. THE METEOR SYSTEM OF WEATHER REPORTING

In April of 1967, the Congress of the World Meteorological Organization met in Geneva, Switzerland. Over 300 scientists from 129 countries discussed a world weather service. Although the meeting coincided with the flights of Kosmos 144 and Kosmos 156, the Russians waited two months before revealing the operational status of their new "Meteor" system of weather reporting.[31]

Even this delayed announcement of the operational Meteor system was later qualified to be referred to as interim in nature. Satellite instrumentation descriptions, although generally compatible, vary slightly from year to year. Thus, when further details of the satellites were supplied in the papers prepared for the 1968 Vienna meetings on peaceful uses of outer space, the television camera resolution was described as 1200 meters, and the two television cameras were described as each covering a path 1000 kilometers wide, with slightly overlapping fields. The control stabilization system was termed unique. As previously mentioned, stability was maintained by flywheels driven by electric motors. The kinetic energy of these flywheels was dampened by using electromagnets on board the spacecraft interacting with the

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[29] Izvestiya, Moscow, March 17, 1967; Aviatsiya i Kosmonavtike No. 9, 1967, pp. 30–35; and Pravda, Moscow, March 9, 1968.
[30] Perry, G. E., The Cosmos Programme, Flight International, London, September 4, 1969, pp. 395–6.
[31] TASS, Moscow, June 1, 1967, 1525 GMT.

magnetic field of Earth. (This has also been used in some U.S. spacecraft.)[32]

The Meteor System includes: (1) artificial Earth satellites, (2) stations for reception and processing data, and (3) service for the control and operation of the on-board systems and their regulation.

D. THE FULLY OPERATIONAL METEOR SATELLITES

The Russians tested individual components of weather satellites in the Kosmos program with a variety of payloads and orbits, culminating in Kosmos 122. The third state of the program involved the interim introduction of the Meteor system with the referenced flights from Kosmos 144 through 226, all launched at Plesetsk.

Yet, the U.S.S.R. did not signal the completely operational status of the Meteor system until 1969 when it began naming certain satellites Meteor, without further designation by number. (Westerners, for convenience, add numbers to the Meteor name.)

1. The Launch Program of the Weather-related Satellites

The table which follows is a summary of the main sequence of similar payloads:

TABLE 5-2—LIST OF SOVIET WEATHER-RELATED SPACE FLIGHTS (MAIN SEQUENCE)

Satellite	Initial Orbital Elements			Launch Date
	Period (min)	Apogee (km)	Perigee (km)	
Kosmos 44	99.5	860	618	Aug. 26, 1964
Kosmos 58	96.8	659	581	Feb. 26, 1965
Kosmos 100	97.7	650	650	Dec. 17, 1965
Kosmos 118	97.1	640	640	May 11, 1966
Kosmos 122	97.1	625	625	June 25, 1966
Kosmos 144	96.9	625	625	Feb. 28, 1967
Kosmos 156	97.0	630	630	Apr. 27, 1967
Kosmos 184	97.1	635	635	Oct. 24, 1967
Kosmos 206	97.0	630	630	Mar. 14, 1968
Kosmos 226	96.9	650	603	June 12, 1968
Meteor 1-1	97.9	713	644	Mar. 26, 1969
Meteor 1-2	97.7	690	630	Oct. 6, 1969
Meteor 1-3	96.4	643	555	Mar. 17, 1970
Meteor 1-4	98.1	736	637	Apr. 28, 1970
Meteor 1-5	102.0	906	863	June 23, 1970
Meteor 1-6	99.5	674	633	Oct. 15, 1970
Kosmos 389	98.1	699	655	Dec. 18, 1970
Meteor 1-7	97.6	679	630	Jan. 20, 1971
Meteor 1-8	97.2	646	620	Apr. 17, 1971
Meteor 1-9	97.3	650	618	July 15, 1971
Meteor 1-10	102.7	905	880	Dec. 30, 1971
Meteor 1-11	102.6	903	878	Mar. 30, 1972
Meteor 1-12	103.0	929	897	July 30, 1972
Meteor 1-13	102.6	904	893	Oct. 26, 1972
Meteor 1-14	102.6	903	882	Mar. 20, 1973
Meteor 1-15	102.5	909	867	May 29, 1973
Meteor 1-16	102.2	906	853	Mar. 5, 1974
Meteor 1-17	102.6	907	877	Apr. 24, 1974
Meteor 1-18	102.6	905	877	July 9, 1974
Meteor 1-19	102.5	917	855	Oct. 28, 1974
Meteor 1-20	102.4	910	861	Dec. 17, 1974
Meteor 1-21	102.6	906	877	Apr. 1, 1975
Meteor 2-1	102.5	903	872	July 11, 1975
Meteor 1-22	102.3	918	867	Sept. 18, 1975
Meteor 1-23	102.4	913	857	Dec. 25, 1975

SOURCE: Appendix A.

[32] See Space Exploration and Applications, issued by the United Nations, covering the meetings of August 14–27, 1968 at Vienna, Austria A/CONF. 34/2. Vol. 1 in the original language of the participants. The papers were made available in mimeograph form as early as the previous April.

Meteor 1 was announced a day after launch as a weather satellite, and given a description indistinguishable from its Kosmos predecessors. The speedy identification of its mission was notable. It was described as reporting on cloudiness, snow and ice cover, both day and night, and on radiation by the Earth and atmosphere.[33]

2. Operation of the Meteor System

Meteor satellites were described as having a strip 1,000 kilometers wide within their observation range, while their sensors of radiation and heat emission cover a territory of 2,500 kilometers.[34] Later, the Russians announced that the vision band in the modified meteorological satellites had been increased by approximately 50 percent.[35]

The data are recorded and stored for release by radio link when the satellites are over Soviet territory. In addition, some satellites now carry automatic picture transmission (APT) equipment making available real time pictures anywhere within receiving range (see below). There are three receiving centers for satellite weather information: Moscow, Novosibirsk, and Khabarovsk. Individual satellite pictures are fitted together to create a large photo montage of the area under study. These pictures are then relayed by phototelegram to Soviet and foreign weather services.[36] According to the Russians, the satellite data are not only used by the Soviet Hydrometeorological Service, but are also instantly relayed to the World Meteorological Service.[37]

Since the early days of the Meteor program there have been a variety of modifications in the Meteor payloads. The Meteor 1–10 satellite launched on December 29, 1971 was the first Meteor that carried APT equipment which is compatible with U.S. APT ground receivers. The Meteor 1–10 was also used to test ion-plasma electrojet engines which use solar energy to create thrust by means of plasma accelerated in electromagnetic fields. The Russians announced that these orbital correction engines were developed to guarantee stabilizing capability for flights of long duration.[38] Also, for the first time, using the orbital correcting engines with the stabilizing plasma engines, it was possible to change the orbital altitude of the satellite by 16.9 kilometers. The higher orbit allowed improved scanning of the Earth's surface and increased the accuracy of the geographic tie-in.[39]

The Meteor 1–8 satellite which was launched on April 17, 1971 contained spectrometric apparatus for determining the vertical temperature profile of the atmosphere to an altitude of approximately 35 kilometers. With this instrument it became possible for the Russians to measure the radiation spectrum of a "column" of air in the infrared range of electromagnetic waves and to determine a vertical cross section of temperature.

The Meteor 2 satellite which was launched on July 11, 1975 represents another change in the Meteor system. According to the Russians the satellite has improved on-board equipment: an experimental

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[33] TASS, Moscow, March 27, 1969, 1625 GMT.
[34] Pravda, Moscow, August 7, 1970, p. 6.
[35] TASS, Moscow, March 4, 1972, 1340 GMT.
[36] Pravda, Moscow, August 7, 1970, p. 6.
[37] TASS, Moscow, April 29, 1970, 1315 GMT; TASS, Moscow, April 30, 1970, 0815 GMT.
[38] Andronov, I., The Meteors Are on Watch, Pravda, Moscow, May 25, 1972, p. 3.
[39] Artsimovich, L. A., et. al., Development of a Stationary Plasma Engine (SPE) and Its Testing on the Meteor Artificial Earth Satellite, Moscow, Kosmicheskiye Issledovaniya, vol. XII, No. 3, 1974, pp. 451–568.

optical-mechanical television scanning apparatus operating in the visible part of the spectrum for obtaining images of cloud cover and the underlying surface; an experimental optical-mechanical television scanning apparatus operating in the infrared portion of the spectrum; and, a complex of radiometric apparatus intended for continuous observations of streams of penetrating radiation in near-Earth space. In addition to the scientific apparatus, the satellite carries a precision electromechanical triaxial system which provides orientation of the satellite toward the Earth, an electrical supply system with independent solar aiming and tracking for the solar cells, a radio-telemetry system for transmitting to Earth data on the operation of the satellite service systems, a radio system for precise measurement of orbital parameters, and a radio complex for transmitting scientific information to Earth.[40]

The Russians continuously stress the benefits derived from weather satellites. Meteorological satellites provide information on clouds, ice cover, and atmospheric radiation. They permit the study of weather fronts and jet stream currents. One article describes the assistance provided by the Meteor satellites during the towing of an unwieldy floating drydock from Klaypeda around the Cape of Good Hope to Vladivostok. The typhoon Juliette threatened to sink the heavily listing drydock, but weather reports from space gave information on the center of the storm and its direction of movement so that a new course could be chosen which saved the drydock and its tugs.[41]

Warnings to populated places of approaching tropical storms have saved many lives. Accurate satellite weather reports have resulted in economic savings as well. The ability to choose optimal routes has meant a sailing time savings of 5 to 7 percent for oceangoing ships.[42] It was estimated that the use of satellite information by the Soviet maritime fleet alone provides an annual saving of over one million rubles.[43] Civil air transports have also benefited from more accurate and timely weather data, particularly information on cloud cover.

The period of navigation along the Arctic route has been considerably extended with the assistance of satellite data on polar ice conditions. The Russians recently published an ice map of the Antarctic in the Moscow journal *Zemlya i Vselenaya* (*The Earth and the Universe*). The map was drawn as a result of an experiment in which the ice boundaries were determined simultaneously by information from two satellites employing two different methods of data collection: a satellite in the Kosmos series measuring the thermal radio-frequency radiation of the Earth in the microwave band, and a Meteor satellite scanning the Earth with a television camera. The two maps compared favorably. However, the Russians concluded that data obtained from measuring the Earth's radiation enjoyed certain advantages. The Earth's atmosphere is virtually transparent to radio waves: neither clouds nor precipitation can block radio waves.[44]

3. Future of Meteorological Satellites

The awarding of the Lenin Prize for 1970 in the field of science and technology for work on the Meteor system is indicative of the

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[40] "Meteor–2 in Flight," Pravda, Moscow, July 13, 1975, p. 3.
[41] Sovetskiy Voin, Moscow, No. 13, July 1970, pp. 35–36.
[42] Andronov, I., Op. cit., p. 3.
[43] TASS, Moscow, February 4, 1975, 1437 GMT.
[44] TASS, Moscow, December 25, 1974, 1425 GMT.

importance the Russians attach to the meteorological satellites, which represent a considerable improvement over Earth-based weather reporting techniques. In a single revolution around the Earth a Meteor satellite collects the amount of data which would require from 15,000 to 20,000 Earth-based weather stations. The Meteor satellites transmit as much data over a period of twenty-four hours as is gathered by all the Earth-based meteorological stations on the planet in 6 months.[45]

Discussions of the future of the Soviet weather observation system include plans for creating a single international network for ocean observations by automatic buoys. Information from the buoys would be collected by radio by satellites.[46]

Also under consideration are the possibilities of creating an international global system of geostationary meteorological satellites which would be placed in synchronous orbit at 36,000 kilometers over the equator. A system of five such satellites could scan a zone along the equator from 50° North to 50° South latitude. The geostationary satellites would be used in combination with low orbiting satellites.[47]

Among future scenarios for Soviet weather reporting is a three-tier system. The orbital altitudes for the three tiers range from several hundreds to 36 thousand kilometers. In the first tier of the weather reporting system there would be long-term orbital manned stations which would make visual observations of geological and meteorological phenomena such as tides, landslides, dust and sand storms, tsunami, hurricanes, and earthquakes. In the second tier Meteor satellites would circle the Earth in polar or near-polar orbits at an altitude of 1,000–1,500 kilometers. Finally, the third tier would contain meteorological satellites at an altitude of up to 36,000 kilometers for continuous observation of the dynamic processes in the Earth's atmosphere such as overall air mass circulation.[48]

E. SOVIET WEATHER ROCKETS

Like many other nations, the Soviet Union also has vertical rocket probe launch facilities for weather reporting purposes. Although the reports are localized, they provide a rapid response and a more complete vertical profile than do satellites. Of particular interest is the rocket sounding station operated by the U.S.S.R. in Antarctica, the world's "weather kitchen". This station is linked by radio with the main meteorological station in Moscow.

F. OTHER WEATHER-RELATED FLIGHTS

Meteorological data were gathered by other experimental satellites outside the main series of flights related to the Meteor series and their precursors. The chief of these are described in the commentary to follow.

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[45] TASS, Moscow, Feb. 4, 1975, 1437 GMT. This is one of the facts from a new book entitled *Kosmos i Pogoda* (*Outer Space and Weather*) published in Leningrad. It is a photographic chronicle of Soviet space meteorology. The authors are designers of rockets and scientific equipment. They have accompanied their text with over 150 color photographs taken from Soviet spacecraft.

[46] Vetlov, I., Celestial Patrol, Izvestiya, Moscow, May 1, 1975, p. 5.

[47] Idem.

[48] TASS, Moscow, May 25, 1972, 0737 GMT.

1. Molniya 1–3 and Molniya 1–4

At least two and perhaps more of the Molniya 1 communications satellites already discussed have carried a television camera in addition to their communications relaying equipment. One of the first revelations came when it was reported that Molniya 1–3 from a height of about 40,000 kilometers had photographed almost a hemisphere of Earth, showing that 80 percent of the visible part of the Northern Hemisphere was cloud-covered. A succession of such pictures during the course of a day was expected to make it possible to trace the formation and movement of cyclones, hurricanes, and other formations important to weather prediction. This was to supplement data from regular weather satellites at much lower altitude. The first picture was taken May 18, 1966.[49]

Further details of the system came with the launch of Molniya 1–4 in October, 1966. The television camera system was steerable from Earth, and included both wide angle and narrow angle lenses, together with various filters, so that several kinds of observations could be made through remote controls from Earth. The purpose, again, was to trace synoptic processes transpiring over large regions of the Northern Hemisphere.[50]

2. Kosmos 149 and 320

Kosmos 149, launched on March 21, 1967, has already been mentioned as a small satellite launched from Kapustin Yar with a B–1 launch vehicle. It represented the first attempt to stabilize a spacecraft through aerodynamic forces while still in orbit. Four rods attached a ring-shaped conic section to the main body of the satellite, and after attaining orbit, the rods were telescoped to extend the ring to a position well back from the main body of the satellite where the very thin upper atmosphere between 240 and 300 kilometers above the Earth stabilized the craft as to pitch and yaw. A two-stage gyro gave stability as to roll. Gas jets were used to achieve the initial stabilization after separation from the carrier rocket, and thereafter no other active devices were required, such as gas jets, reaction wheels, orientation sensors, or other attitude controls.

The satellite had two multichannel photometers to scan the Earth in two mutually perpendicular directions, to determine Earth brightness in a narrow region of the spectrum including the molecular absorption band of the visible region. Another instrument was a radiation meter in the 8 to 12 micron visibility window to measure the radiation temperature to an accuracy of 1 degree Centigrade. The TV system on board measured escaping radiation only in narrow regions of the spectrum in contrast to the wide spectrum coverage of the TV system used in Kosmos 122 and 144. The data returned to Earth concerned the temperature regime of Earth's surface and clouds along with quantitative characteristics of the brightness of Earth as seen from space. The payload decayed in 17 days.

Kosmos 320 had the same characteristics of orbit, and remained in orbit for 25 days. Similar results were obtained from the second flight.

3. Kosmos 243

This satellite has already been described as a regular military observation satellite, recovered after 11 days in orbit. But it also carried

[49] Izvestiya, Moscow, May 20, 1966, p. 6.
[50] Krasnaya Zvezda, Moscow, October 22, 1966, p. 1.

a supplemental scientific payload, designed to explore some of the areas of shortcoming of conventional weather satellites. The Meteor satellites are unable to penetrate thick cloud cover. Consequently, for the first time, experiments were carried to study thermal radiation of the Earth from the atmosphere and surface in the 8 mm to 8 cm wavelengths. The sensors were oriented toward Earth, constituting an automatic radioastronomical observatory in space. There was also a narrow-band infrared receiver.

Among the possible measures from such studies are the water drop content of clouds, and the foci of precipitation previously obscured by cloud cover. Further, measuring the water vapor resonance attenuation of these wavebands against corresponding wavebands permits the determination of the humidity of air. Also, the satellite was able to measure solid ice limits in Antarctica despite cloud cover, and to give a profile of Pacific Ocean surface water temperatures from the Bering Sea to Antarctica.[51]

IV. Navigation Satellites

An earlier section of this report explained that the Soviet Union acknowledges its use of navigation satellites, but does not explicitly identify any particular flight as used for that purpose. Hence, it is assumed that in the early stages such flights serve military purposes in the same way that the United States developed Transit first for use with its Polaris submarines, and then by stages extended the use to other naval vessels, and now makes navigation satellite data available to merchant ships of any nation willing to acquire the necessary receiving equipment and computers which permit use of the data on satellites, from which ship position may be derived.

It is possible, even probable, that a similar transition is occurring within the Soviet navigation satellite program. and thus in time, the flights will be identified, as they must be if merchant ships or aircraft are to use them on an open, unclassified basis, or if international use is to be made.

A. Soviet References to Navigation Satellites

Leonid Sedov stated as early as 1965 that space was already being used for communications, weather reporting, and preparation of precise maps of the world.[52] In January 1966, the new Five Year Plan made specific reference to using space for communications, weather reporting, and navigation.[53]

Mstislav Keldysh was quoted shortly thereafter as saying that "The utilization of satellites and rockets for radio and television communications, navigation, and meteorology has been put into operation." [54] He repeated similar words at a meeting of the Soviet Academy of Sciences held June 27, 1966. He made similar statements in April 1967, and in November 1967.[55]

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[51] Pravda, Moscow, January 21, 1969, p. 3.
[52] TASS, Moscow, December 31, 1965, 1612 GMT.
[53] TASS, Moscow, January 5, 1966, 1130 GMT.
[54] Pravda, Moscow, April 3, 1966.
[55] Moscow Radio, April 12, 1967, 1355 GMT; Moscow Radio, November 5, 1967, 0905 GMT.

One of the most explicit references to Soviet navigation satellites appeared in 1966 in a magazine article which stated that the precision of such devices is constantly improving as reference points for shipboard and aircraft navigation systems. Coordinates can be determined to an accuracy of 200 meters.[56]

A short book devoted to the subject was issued in 1969.[57]

A 1968 broadcast mentioned a proposal for an air and ship navigation and traffic control system which would use 24 satellites to give complete coverage. There is no positive clue that such a system is in the process of being implemented at the present time.[58]

Finally, as mentioned earlier in this study, in connection with the launch of 8 satellites by one launch vehicle on April 25, 1970, an article in Red Star hinted vaguely at the uses of such multiple launchings—for science, communications, and navigation; watching ionospheric processes; and radio astronomy by the interferometer technique. This is not sufficiently specific to be conclusive, for any one of these uses, although today the preponderant Western view is that they serve a communications purpose.

Recent mention of navigation satellites or a navigation satellite system are noticeably absent from the Soviet press.

B. ACTUAL NAVIGATION SATELLITE FLIGHTS

(See the section in Chapter One on the use of the C–1 vehicle, and the sections in Chapter Six on navigation satellites.)

V. Earth Resources Satellites

The Soviet Union has shown a definite interest in Earth resources satellites. However, it does not have an operational program at the present time. It remains unclear from Soviet accounts whether they propose to create unmanned systems for gathering Earth resources data on a regular operational basis, or whether such work will be held in abeyance until an operational manned space station is formed.

At a scientific conference held in Zvenigorod, near Moscow, the problems of studying the Earth from space were discussed. Commenting on this conference, Academician Roald Sagdeyev, director of the Space Research Institute, the Soviet Academy of Sciences, stressed that the main task of the conference is to work out unified scientific principles and methods for exploring the Earth's resources from outer space and for organizing systematic control over the environment with the help of artificial satellites. Sagdeyev mentioned the international aspects of Earth resources study: man-made influences on the environment reaching beyond national borders, and the assessment of natural resources from space for the developing nations. Although Sagdeyev called for international cooperation for a global Earth resources monitoring system, there was no mention of immediate plans for an operational system for the U.S.S.R.[59]

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[56] Nadezhdin, D., Space Science in the Service of Mankind, Sovetskiy Patriot, Moscow, June 22, 1966, p. 4.

[57] Sivers, A. P., and Yu. I. Tarakanov, Kosmos i More, Leningrad : Izd-Vo "Sudostroyenyi", 1969, 87 pp.

[58] Moscow Radio, April 1, 1968, 1400 GMT.

[59] TASS, Moscow, March 13, 1975, 2015 GMT.

However, it was announced at the conference that initial steps had been taken to establish a research center, Kaspii, its purpose to develop new methods of using remote sensing to study the natural resources of the Caspian region. The conferees were also informed that plans were underway to build a central scientific institution to study the Earth's resources from space.[60]

A. EARTH RESOURCES DATA FROM THE METEOR SATELLITES

Geologists were among the first to use space photographs. They have long used aerial photography for research. However, the maximum area of the Earth's surface that can be photographed at any given time from an aircraft is 1,000–2,000 square kilometers. The dimensions of geological structures—folds, depressions, and faults in the Earth's crust—are measured in hundreds and thousands of kilometers. Such large geological formations can only be seen as a whole from space.[61]

Soviet geologists cite numerous geological discoveries resulting from the use of space photographs. Images of the Earth from space have enabled geologists to see faults which have not been discovered by ground expeditions. They have also been able to correlate such geological anomalies with mineral deposits and increased seismic activity.[62] Russian scientists also claim that satellite imagery led to the discovery of iron at Malyy Khingan and coal in the Amurskaya Oblast.[63]

Geologists in the Soviet Union are now revising existing geological maps. Many regions which earlier had been considered well explored geologically, such as the Urals and the Caucasus, have appeared entirely different after a space survey.[64] Thus, a space map of a territory comprising 6 million square kilometers has enabled the All-Union Aerogeological Trust to formulate new theories about the tectonic structure of the region.[65]

Using satellite images Soviet agronomists can monitor crop growth over large areas. It has also been discovered that with satellite photos it is possible to detect the degree of moisture of various types of soil—from the most arid desert to irrigated farm land.[66] More accurate information on snow cover in the Tien Shan and Himalaya Mountains has enabled farmers to irrigate the crops more effectively. Space surveys also make possible the study of the formation and dessication of intermittent lakes.[67]

In the future the Russians plan to use Earth resources data from space in a variety of fields. Space surveys will be used for estimating crop yields and monitoring insect infestation. Forests and large land reserves will be monitored for blights as well as for fires.[68] In 1971 an article appeared which claimed that scientists were using only 40 percent of the information contained in space imagery. The author

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[60] TASS, Moscow, March 10, 1975, 1757, GMT.
[61] Andronov, I., Op. cit., p. 3.
[62] Idem.
[63] Pushkar, A., High-Altitude View, Izvestiya, Moscow, August 5, 1975, p. 5.
[64] Bryukhanov, V., Aerogeologiya Trust, Orbital Geology, Izvestiya, Moscow, July 25, 1974, p. 2.
[65] Op. cit., p. 3.
[66] Vinogradov, B. V., and A. A. Grigor'yev. Viagooborot V Prirode i Yego Rol'v. Formir, Moscow. Resursov Presn Vod, Stroyizdat, 1973, pp. 204–217.
[67] Idem.
[68] Andronov, I., Op. cit., p. 3.

stated that in the future advances in photointerpretation must allow the Russians to utilize the remaining 60 percent of the information contained in space photos. Improvements in resolution will enable agronomists to see finer features on the Earth's surface. To be of maximum use, such detailed photographs should be available on a daily basis.[69]

Eight Soviet scientists met with U.S. experts on the remote sensing of geology and agriculture in Sioux Falls, South Dakota in October 1975. NASA and U.S. Geological Survey representatives and several members of the Soviet delegation reviewed the results of the two nations' previous remote sensing projects in geology and considered possible future work in this area. Several of the Soviet scientists attended the first William T. Pecora Symposium on the applications of remote sensing to mineral and mineral fuel exploration held in Sioux Falls, October 28–31, 1975.

Other Soviet scientists will visit an agricultural area used as a test site for interpreting and evaluating data gathered by aircraft and satellites. (In 1974, American scientists visited a comparable Soviet test site near Kursk in the Ukraine.) Discussions with U.S. Department of Agriculture scientists are also planned.

This cooperative effort by NASA and the Soviet Academy of Sciences is one of several undertaken following an agreement reached in 1971 and formally endorsed at the May 1972 Moscow summit meeting. Another scientific exchange occurred in early 1973, when NASA and the Soviet Academy conducted an intensive study of the Bering Sea using satellites, aircraft and research ships to evaluate the usefulness of remote sensing for studies of sea ice conditions.

In an effort to improve remote sensing capabilities Soviet scientists are seeking ways to determine the vertical profile of temperature change beneath the ocean surface, chemical composition and salinity of the water, its chlorophyll content and evolution of turbulence and wind conditions at the surface from space imagery. Such information would be of great value to fishing interests.[70]

B. MANNED FLIGHTS GATHERING EARTH RESOURCES DATA

The earlier section on manned flights has already treated the increasingly heavy emphasis which has been placed on gathering Earth resources data in manned flights, particularly in the Soyuz and Salyut programs. Soyuz 9 during the course of its 18-day flight went quite far in this regard, both because of the amount of time available for such pursuits and because it built upon the more limited experience of its predecessors. There is no necessity here to repeat the list of measurements made by the Soyuz flights. The Salyut flights have further extended this effort.

C. PERMANENT SPACE STATIONS

Articles on the future study of the Earth from space inevitably mention the desirability of permanent space stations. Russians place a high priority on the development of manned space stations. Discussion of Earth resources experiments has already described some of the

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[69] Wazirov, M., Satellites for the Agronomist, Zemlya Vselennaya, No. 1, Moscow, 1971, pp. 76–77.
[70] Kondrat'yev, K., Cosmic View, Izvestiya, Moscow, January 22, 1975, p. 3.

experimental techniques that have been tried in connection with the Soyuz and Salyut manned flights. Many Soviet writers stress using manned flights and manned stations rather than unmanned satellites for future operational Earth resources work.

Of course, the potential uses of manned stations extend beyond Earth resources work. Cosmonaut Pavel Popovich has discussed the future use of manned stations for purposes of weather reporting, astronomy, navigation, and data relay. These manned stations would be supported by reusable shuttle craft, using conventional airfields for takeoffs and landings.[71]

A detailed list of functions for such stations was provided by Yu. Novikov in 1969, which in effect summarizes much of the discussions on such stations. He listed the advantages of optical and radio astronomical observations from beyond the atmosphere, the development of topographic maps of Earth, including underwater relief, the location of mountain and valley glaciers, lakes, flood plains, and deltas. He foresaw the ability to predict high water, salinity, location and amount of industrial wastes, ocean salinity, measures of crop maturity and detection of crop pest and disease infestation, and forecasts of crop yields on a timely and regular basis.[72]

G. I. Petrov attempted to translate the advantages of stations and other satellites into economic terms, suggesting that weather satellites alone could with a five-day accurate forecast save the equivalent of $6 billion a year. He foresaw in the more distant future, accurate forecasts of weather an entire year in advance, with enormous savings. He expected that high energy physics laboratories built in orbit would be far cheaper than corresponding laboratories on the surface of the Earth. Also, he saw space work leading to weather modification.[73]

More fanciful articles have envisioned the ultimate erection of whole cities in orbit, with these space bases used not only for the kinds of observational and relay missions heretofore described, but also for assembly and fueling of deep space craft to fly to the Moon and to other planets.

This Soviet emphasis on the numerous current and potential benefits of the space program is indicative of the Soviet belief in the usefulness and bright future of applications of space technology to man's needs.

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[71] Popovich, P., A Look Into the Future, Grazhdanskaya Aviatsiya, Moscow, No. 10, 1967, p. 10.

[72] Novikov, Yu., Orbital Stations; A Glance into the Future, Tekhnika Molodezhi, Moscow, Nov. 3, 1969, pp. 22–23.

[73] Petrov, G. I., Why Master Space?, Znaniye-Sila, Moscow, No. 7, 1967.

CHAPTER FIVE ANNEX

THE MOLNIYA COMMUNICATIONS SATELLITES

By Geoffrey E. Perry*

The Molniya communications satellites are placed in highly elliptical orbits (eccentricity—0.74) with perigee in the southern hemisphere. The orbital period is some 3.3 minutes less than 12 hours so that, despite the very small precession of the orbital plane and the motion of the Earth around the Sun, the ground-track repeats itself, albeit a few minutes earlier each day. Such an orbit, with repetitive ground tracks, may be said to be stabilized.

Initially all Molniya satellites were launched from Tyuratam into orbits inclined at 65.0° to the Equator. Dr. R. R. Allan, of the RAE, has shown that the 4th Molniya 1 was the first to use a stabilized ground-track.[1] The 5th Molniya 1 was not stabilized and the 6th and 7th only partly stabilized. Thereafter the correction engine has been used to stabilize all Molniya ground-tracks.

The initial method of achieving a stabilized ground-track was to place the satellite into an intermediate orbit with period of the order of 700 to 710 minutes. This resulted in an eastward drift of ground-track of between 3° and 8° per day. When the ground track had drifted to the desired position, a firing of the correction engine at perigee raised apogee to produce the stabilized orbit. The times elapsing between launch and stabilization ranged from 8 to 20 days.

The launch of the 13th Molniya 1 signalled a move to the Plesetsk launch site and orbital inclinations of 65.4°. A similar stabilization technique was employed. The change of site was a transfer of routine launches from Tyuratam rather than to reduce the time delay between launch and stabilization of ground track. The 15th Molniya 1 was not ground-track-stabilized until the 60th revolution, 30 days after launch.

All Molniya 2 satellites have originated from Plesetsk, as have the four Molniya 3's, and only four later Molniya 1's have been launched from Tyuratam and these during winter months.

The 7th Molniya 2 satellite and all subsequent Plesetsk-launched Molniyas have flown at an orbital inclination of 62.9°. The change in inclination resulted in a new stabilization pattern. The satellite is placed into an intermediate orbit with a period of between 730 and 740 minutes producing a westerly drift of ground-track of around 10° per day. This has permitted stabilization by lowering apogee within 4 or 5 days of the launch.

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*Mr. Perry is senior science master at the Kettering Grammar School, Kettering, England.

[1] Allan, R. R., The operation of Molniya communications satellites, Tech. Report 69266, R.A.E., November 1969.

The early history of the Molniya satellites has been described by Allan[2] who pointed out that the 8th, 9th, and 10th Molniya 1's constituted a three-satellite system with orbital planes spaced at approximately 120° intervals providing a complete 24-hour coverage of the U.S.S.R. Each satellite repeated the ground track of its predecessor some 8 hours later in time. He also speculated that the 11th and 12th Molniya 1's might be the pioneers of a four-satellite system with orbital planes spaced 90° apart and satellites following each other at 6-hour intervals.

In 1974, Philip Perkins and Geoffrey Perry, of Kettering Grammar School, developed a simple graphical method for monitoring the operational status of Molniya satellites in the Orbita system. Using data supplied by the Goddard Space Flight Center, they plotted the values of the right ascension of the ascending nodes against date and obtained a series of four straight lines spaced at 90° intervals, confirming Allan's hypothesis.[3] From this they were able to trace the history of replacement of the Molniya satellites as they reached the ends of their active lives. Labeling the four groups of satellites from A through D, the replacement history of the Molniya 1's is seen to be as shown in the following table:

TABLE 5A-1.—REPLACEMENT SEQUENCE OF MOLNIYA 1 SATELLITES

A	B	C	D
11			
	12		
		13	
			14
	15		
			16
17			
		18	
	19		
20			
21			
			22
		23	
	24		
25			
		26	
			27
		28	
29			
	30		
		31	

SOURCE: After Perkins and Perry.

The 1st Molniya 2 was positioned approximately mid-way between groups A and D of the Molniya 1's and, when the 2nd Molniya 2 was positioned mid-way between groups A and B, the possibility arose that the Molniya 2's were a supplementary system to fill gaps in the existing system. However the 3rd Molniya 2, between groups B and C, was spaced 120° away from the 2nd; i.e., nearer to group C. Although these first three Molniya 2's did not join the Molniya 1 groups, thereafter, all Molniya 2 launches have added their payloads to those groups. The sequence of replacement is given in the following table:

[2] Ibid.
[3] Perkins, P. J. and G. E. Perry, Flight International, London, *107*, 79, 16 January 1975.

TABLE 5A-2.—REPLACEMENT SEQUENCE OF MOLNIYA-2 SATELLITES

(D)	A	B	C	D
	1			
		2		
			3	
				4
		5		
	6			
				7
			8	
	9			
		10		
				11
			12	
	13			
	14			
		15		

SOURCE: After Perkins and Perry.

When the Molniya 3 satellites were introduced they joined groups C, D, A and B in turn over a 13 month period. The orbit of the fourth and latest in the series was stabilized on January 1, 1976. The close proximity of the members of each group can be seen from the times and longitudes of their ascending nodes as of January 2, 1976.

TABLE 5A-3.—TIME AND LONGITUDE OF MOLNIYA ASCENDING NODES

Group	Satellite	Rev Number	Time (GMT)	Longitude (°E)
B	Molniya 2-15	32	0201	68
	Molniya 3-4	12	0205	68
	Molniya 1-30	424	0217	60
A	Molniya 3-3	98	0706	74
	Molniya 2-14	232	0735	66
	Molniya 1-29	498	0746	67
D	Molniya 2-11	758	1336	71
	Molniya 1-27	1,248	1411	63
	Molniya 3-2	528	1416	64
C	Molniya 2-12	664	2009	66
	Molniya 3-1	818	2015	64
	Molniya 1-31	246	2018	61

Consideration of these times and longitudes provides an explanation for the replacement of the 13th Molniya 2 by the 14th after only two months. Presumably launched to ensure optimum communications during the Apollo-Soyuz mission in the following week, the orbit was never properly stabilized. The orbital period was lowered to 718·6 minutes but no further correction was made. Consequently, although still in the same orbital plane as the other members of Group A, it fell further and further behind in time and consequently drifted off station in a westerly direction. By January 2, 1976 it was crossing the Equator 198 minutes after its replacement and at 7°E. By then, luni-solar perturbations had reduced the period to 717·5 minutes and the ground-track was temporarily stabilized, although in the wrong position.

As has already been mentioned in another section of this report, certain satellites in the Kosmos series have flown in orbits similar to those of the Molniya satellites. With the exception of Kosmos 41

which was, most probably, an engineering test as part of the R & D leading to the establishment of the Orbita system, it was at one time tempting to regard such satellites as Molniya failures. Whilst it would appear from consideration of orbital plane spacing that the 6th Molniya 1 replaced Kosmos 174 within 33 days of its launch [4] and that Kosmos 260 could have been a replacement for the 8th Molniya 1, such an assumption is not valid in the cases of Kosmos satellites launched since 1972. Perry pointed out that the orbital plane of Kosmos 706 does not coincide with any of the four groups.[5] Neither do the planes of Kosmos 520, 606, and 665, although the planes of Kosmos 520 and 606 are close enough to each other for one to have been a replacement for the other.

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[4] Flight International London, *92*, 628, 12 October 1967.
[5] Perry, G. E., Fight International, London, *107*, 686, 24 April 1975.

CHAPTER SIX

SOVIET MILITARY SPACE ACTIVITIES

By Charles S. Sheldon II*

I. Introduction

A. DEFINITIONAL UNDERPINNINGS OF MILITARY SPACE ACTIVITY

More than half of Soviet space launchings to date have been in direct support of military missions. Table 6–14 at the end of this chapter will summarize trends in this regard. Chapter One, Tables 1–2 and 1–3 gave the basic information on which the table in this chapter reached its findings. While these tables show the great importance of military applications in the Soviet space program, they also show that the program is not wholly military in its objectives. Other chapters discussing the organization, the goals, and the hardware of the Soviet program show the many elements of the program used for scientific and civil or economic applications, which make the diversity of the total program abundantly clear.

There has always been an element of speculation about Soviet purposes in space because of their skillful use of information policies to combine a large flood of information about many aspects of space flight, including the quick identification of flight names and orbital parameters, and at the same time they have a policy of tight security and secrecy over the real purposes of most payloads and minimal information about the technology of Earth orbital flight. Earlier chapters of this report have shown techniques for penetrating this obfuscation to provide fairly reliable indicators of real Soviet objectives, flight by flight. If this is not possible on the day of launch, particularly with new variations, this usually can be accomplished within a year or two by painstaking analysis of all the evidence which finally enters the public domain. It is partly a subjective judgment in the end, without Soviet cooperation, whether we have really explained all flights or whether there is a remnant where even our "guesstimates" and intuitive feelings may be misleading us. In general, experience seems to demonstrate that our more conservative views about mysterious flights in the end find better support than the more speculative guesses that a particular new event is about to lead immediately to quantum jumps in ambitions and achievements.

The Russians have maintained they must pursue policies of secrecy over some aspects of their flight program because they do not want to boast in advance of concrete accomplishment—which is just another way of saying they hate to tarnish their contrived image of superiority by admitting to failures which inevitably occur in all space programs

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pushing into new technology. They also admit that most of their launch vehicles have also been used as military missiles, and hence their characteristics must be protected against disclosure to their foreign rivals if their strategic deterrent against aggression by imperialists is to be preserved. This is hard to understand when Moscow parades have included the Shyster, Sandal, Skean, Sasin, Scarp, Scrag, and Savage, among others, while they have held back pictures of the complete D (and G) class vehicles, as well as details on some or all upper stages of A, C, D, and F class launch vehicles. The Russians have routinely made clear that all their launches are conducted by the Soviet Strategic Rocket Forces, a military organization.

The Soviet claim is that all of their space flights are peaceful and scientific, while in earlier years it was common for them to attribute aggressive motives and see complete military domination in the United States program. The problem of penetrating political semantics for scholars in a truly neutral setting, looking at claims and counter claims, is not necessarily difficult, but is partly a matter of philosophy rather than absolutes. For some years, the United States has stated that its own space program is wholly peaceful—using space through the National Aeronautics and Space Administration (NASA) and other civilian departments to help us live better in peace, and using space through the Department of Defense (DoD) to guarantee the peace. This country remains at least as reticent as the Soviet Union in refusing to disclose real details about the central military missions in space, although we acknowledge we are withholding, while the Russians pretend they have no military space program to withhold. A similar Soviet claim that their space program is wholly scientific is valid to the extent that science and technology are treated as synonymous. This kind of melding or loose use of categories is present in American journalism and politics where all engineers, administrators, and technicians associated with the space program become "scientists" for labeling purposes. Obviously, space technology is based upon scientific principles, but then so are virtually all things mechanical and material in human affairs, without being called "scientific".

Perhaps the real tests of peacefulness or aggression lie not in labels or organizations but in intentions. Some specific acts in the space field are viewed as warlike: These include placing weapons of mass destruction in orbit—now banned by treaty among the major powers—and direct interference with the flights of other nations. Beyond that, classifications become more nebulous. Protective development of technology which could be used in combat is not an act of war, but may be viewed either as defensive prudence, or as as escalation of the arms race. Traditionally, sailing men of war on the high seas and making peaceful port calls are also subject to multiple interpretations. It may be thought a way to instill confidence that tranquility will be maintained, or it may be "gunboat diplomacy", at least as a threat. Likewise, the bulk of space flights with military characteristics in both the programs of the United States and the Soviet Union are passive in character and neither violate any treaty nor pose any threat in themselves to other nations, yet are criticized by some other nations.

One can go on as do propagandists and even some professional military writers to wax wrathful over the threats of space reconnais-

sance, navigation, weather reporting, communications, and so forth, but this involves highly subjective judgments. Either it represents a one-sided assessment of the potential disadvantages without regard for the benefits which also exist; or it is a wishful desire for a simpler age without technology and a peaceful world without threat of military force. Military opponents may be tacitly thinking in terms of space hegemony for their own nation and the exclusion of other powers from military space use.

When one tries to sort out individual space flights into categories which are predominantly civil or military, it quickly becomes apparent that it cannot be done by administering agency alone because a simple administrative change in titles of government departments could upset classifications. The inherent peaceful or warlike character of flights is not easily answered by the hardware and flight path, because this depends partly on states of mind and intended end objectives, not always apparent. For example, when is a weather report just an economic fact for a farmer, and when is it a guide to the commander of a strategic bomber force? When is an observation flight one to gather economic data to raise the world standard of living, and when is it a safeguard against surprise attack to keep the world peaceful, and when is it a means for upgrading target information for future conflict?

This chapter does not try to settle such philosophic issues of whether a weather report is peaceful or aggressive in the minds of the recipients. It cannot debate whether a military satellite relaying inventory data on socks and shoes in a supply depot is more peaceful or less than another message on trade data related to international markets passed among multinational corporation offices. Its pragmatism will be apparent in the sections which follow, and it does not offer judgments as to what is inherently good or bad.

Both the United States and the Soviet Union have been reasonably aware of trends in each other's military doctrine, hardware, and policies. They have developed whatever space systems they have from the same fount of worldwide technology, although advancing some parts of this knowledge and know-how at different rates depending upon their concentration of manpower and resources in particular areas. The United States began in the Department of Defense its Discoverer flights as early as 1959. The Soviet Union introduced the Kosmos label in its flights beginning in 1962. Both countries had to have started the technology of military space uses far earlier to be able to meet the lead time requirements of such flights. The U.S. earlier start in military applications is matched by its similiar earlier start in civil applications.

B. SOVIET STATEMENTS ON SPACE FOR MILITARY PURPOSES

This section reviews Soviet statements on military uses of space to a degree sufficient to supplement other analytical techniques in understanding the development of their military space program.

Not surprisingly, a primary journal for articles of analysis of the military aspects of the U.S. space program has been *Red Star* (*Krasnaya Zvezda*). Retired Major General Teplinskiy wrote a long diatribe on U.S. activities, in which he claimed that the Apollo program

aimed at prestige was a disappointment to Pentagon leaders, and then he developed the theme that most of the associated work of Mercury, Gemini, and Apollo really served military ends. He further attributed to the United States a long list of military missions ranging beyond military support work to space interceptors and orbital bombs.[1]

This was followed by a more detailed analysis of U.S. military space activities about two weeks later in the same paper. It traced work in geodesy, photographic observation, infrared detection of missile launchings, weather reporting, military communications, navigation—all reflecting a detailed familiarity with the spate of stories carried over the years in the American trade press. But the author went on to ascribe to U.S. planners schemes for stationing nuclear bombs in orbit, and armed interceptors for battle against other spacecraft. Dyna-Soar was discussed, with the Gemini-derived Manned Orbiting Laboratory (MOL) identified as an even more formidable successor. The article concluded that no matter how ambitious U.S. military plans were, they would always be exceeded in space by the combat might of the Soviet armed forces.[2]

Attacks on U.S. policy were extended in October 1965, contrasting the purported scientific idealism of the Soviet Union with the claimed determination of the United States to pursue aggression by unleashing a new world war which would include war in outer space. Samos, Transit, and Secor (experiments related to observation, navigation, and geodesy respectively) were singled out for special criticism, together with experiments conducted by the Gemini 5 of infrared observation of a missile launching, and especially the threat of MOL.[3]

In 1966, this same theme was carried by Moscow Radio:

> It is quite clear that these mad plans and insane aims of the nuclear maniacs with regard to space and the celestial bodies must alarm world opinion. All of mankind is interested in barring the road toward transforming space into an arena of military rivalries. The U.S.S.R. which was the first to open the way into space, has always been careful to conduct research and the conquest of space for peaceful purposes, for the good of mankind. The scientific, technical, and biological facts obtained as a result of the launching of spaceships and Earth satellites are mostly published in the Soviet press and have become aids to world science.[4]

Although these several quotations are only illustrative, they indicate much of the general tone of Soviet pronouncements over the years. But times are changing, and some quite interesting statements have been made by Soviet authorities in other settings. *Pravda* quoted Party Chairman Brezhnev himself in 1966 at a reception for Soviet military academy graduates at the Kremlin on July 1, 1966:

> A host of all kinds of fabulous stories is now in vogue in the United States—that it has the most "all-seeing" spy satellites, the "greatest possible number of rockets," the most "invulnerable submarines" and so forth and so on. But to put it mildly this does not agree with the facts, since the authors of such stories rely on those simpletons who have never considered what rockets, sputniks, submarines, and other technical equipment the Soviet Union has.[5]

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[1] Teplinskiy, B. The Pentagon, the Mad Men, and the Moon. Red Star, January 10, 1965.
[2] Glazov, Col. V. Cosmic Weapons, Red Star, January 26/27, 1965.
[3] Golyshev, Col. M. Military Review—The Pentagon is Pushing toward the Cosmos, Izvestiya, Moscow, September 28, 1965.
[4] Moscow Radio, August 21, 1966, 1730 GMT.
[5] Pravda, Moscow, July 2, 1966.

Equally interesting was the interview carried in Yugoslavia with Konstantinov of the Soviet Academy of Sciences:

> Space research is not so expensive as it is useful. Not only because it promotes science and develops technology, but it also has great economic importance . . . it makes possible increasingly precise weather forecasts, it facilitates air and sea navigation, it makes topographic registration and geological research simpler . . . and its importance for defense is enormous. It is known how much trouble the United States had when it sent spy planes to take pictures of U.S.S.R. territory from a great height. Such spy planes have becomes useless . . . The results of space research make mankind happier because it feels surer that it will live in peace.[6]

Colonel Yuriy Gagarin was somewhat defensive about Soviet space activities:

> With wonderful refinement they try to misinterpret, slander, and belittle, and when this does not succeed, simply maintain silence concerning our achievements. Frequently my professional colleagues and I have had to listen to questions such as: "Aren't the Russians trying to 'militarize' space? Don't we intend to build rocket bases on the Moon? . . . A lot of such rubbish has been thought up. It is hardly worth replying to these "you knows" and "whys". However, I will make a clean breast of one of them. Yes, the majority of those who tested the Vostoks and Voskhods were by profession military pilots . . ."[7]

The Czech press reflected some of the realities of military support flights in a 1969 article:

> It is no secret that many cosmic bodies which are orbited and still orbit our planet have also strategic military importance apart from scientific mission. Literally every square kilometer of our planet is being watched by the cameras of these messengers of human reason. It is necessary that imbalance should not appear and last for a long time in this competition, that politicians should be able to take prudent decisions in time and thus forestall a catastrophe from time to time threatening the destiny of mankind, once in a rather concealed way and more strongly at another time.[8]

It may be interesting to note the text of an article appearing in Moscow on the intelligence services which seems to give tacit approval for the use of reconnaissance satellites:

> Let us repeat, the division of labor within the intelligence service in no way signifies a desire on the part of its leaders to have clean hands; on the contrary they use secret agents to fulfill the most serious and profound tasks which cannot be solved by satellites, reconnaissance aircraft, or information centers using fast electronic equipment.[9]

The distinction was being drawn between human spies (necessary, but dirty) and modern technology (necessary and correct, if not applauded).

The point of these selected quotations is that the Soviet Union has worked at the game of making the United States look as bad as possible in doing what it believes is necessary in defensive military space technology, while keeping its own freedom of action in this regard as complete as possible. In the late 1950's and early 1960's, the Russian charges were close to hysterical against the United States military involvement in space. In the middle 1960's, they continued to point with disapproval, and to charge that the United States would move beyond support work to space weapons. In the most recent past, they

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[6] Butorac, T. Interview with B. P. Konstantinov, vice president of the Soviet Academy of Sciences, Vjesnik Zagreb, January 21, 1968, p. 8.
[7] Red Star, February 22, 1968, p. 4.
[8] CTK, Prague, July 22, 1969 0819 GMT, quoting Rude Pravo, the Communist Party daily.
[9] Nedelya, Moscow, No. 46, November 9–15, 1970, pp. 14–15.

may still make token charges, but the general tone is more muted, and there is more indirect acknowledgment that space defense work is useful to both nations. This has even advanced to the point where SALT talks on limits to weapons refer to use of "national technical means" (unspecified, but not excluding space) as a method for each nation to verify the conformance of the other to whatever limits are agreed to in construction and deployment of weapons and defenses.

In one respect, the Soviet Union, which leveled so many unfounded charges against the United States for planning to put weapons into space, has itself exceeded U.S. intentions and actions. This has been in its creation of the fractional orbit bombardment system (FOBS) and an inspector/destructor system. Both of these will be discussed later in the chapter.

II. Extension of Civil Type Space Activities to Military Needs

It is difficult to pinpoint military use of satellites when the same kinds of missions are normally carried out for civil purposes as well. As a consequence, no attempt can be made here to quantify what part of the hardware or the usage of shared hardware is for military purposes. The primary purpose of this section is to discuss in more general terms that such military uses do lie within some categories of flights.

A. WEATHER REPORTING

A previous chapter explained the Meteor weather satellite system which is a general purpose activity serving many customers. Weather reports are important to agriculture, fisheries, water resource management, and many other economic users. Weather reports are especially important to aviation and shipping services of any description. Every military branch in any nation also requires weather information. In the United States, the weather satellites of the National Oceanic and Atmospheric Agency (NOAA) and NASA are coordinated for data purposes with a Defense Meteorological Satellite System, and hence the flow of information from all these systems moves into the mainstream of shared weather reporting.

It would not be credible if the Meteor system results of the Soviet Union were not made available to their military users as well as the national economy.

Philip J. Klass, the senior electronics editor of *Aviation Week* magazine, has long believed that the Soviet Union has a military weather satellite system as does the United States. He credits the B–1 launched small satellites from Plesetsk as the carriers of such cameras, because he has found some correlations of launch times of these with Soviet military observation recoverable flights. He suggests such military weather satellites guide the larger recoverables in their expenditure of photographic film. This report does not accept this hypothesis because it is believed by now there would be some direct evidence in signals from these craft if this were the case. One can conceive of such signals being in frequencies and emitted at places in the interior of the Soviet Union to hide their function from Western listeners, but this represents a degree of security more extreme for a relatively

passive mission which is out of proportion to Soviet security in other military space missions.

The Meteor satellites and certain seasonal flights of the military photographic recoverable series flown to high latitudes are used to give weather coverage of the Soviet Northern Seas Route across the top of Eurasia. Soviet naval vessels are moved between such ports as Murmansk or Archangel and Petropavlovsk or Vladivostok through this route, when ice conditions permit, saving the long trip around Africa (or Suez, when open).

B. REGULAR COMMUNICATIONS

Another chapter of this report has also discussed communications by satellite, using the Molniya system. Again, it is impossible to say what proportion of total traffic handled through Molniya is of a military nature. The Russians have announced the system not only handles television broadcasts but also telephone, telegraph, and other data transmission. We know that the Molniya is used as a relay for space-related data transmitted between satellites and ocean tracking ships, to extend this link on to Yevpatoriya and Kaliningrad, among other points.

There are now more Molniya satellites active than are required for likely civil purposes. For example, the Molniya 1 satellites operate in one frequency range, while a successor Molniya 2 series operates at higher international frequencies, both in support of the Orbita ground station system. As described earlier, each of these Molniya systems keeps a Molniya 1 and a Molniya 2 always in sight of the home territories by spacing the orbits 90 degrees apart, with four type 1 and four type 2 satellites in operation. As of this writing, the Molniya 3 series do not yet make up a complete pattern of four. By Soviet description, Molniya 2 now takes care of regular domestic television programs, and Molniya 3 has an operational capability for color television (as well as probably serving the Soviet-American hot line link). But Molniya 1 replacement flights continue to be made. Mindful that in the United States, some older trunk telephone links not up to current commercial standards are leased to the Government, one wonders whether the Molniya 1 satellites are not relegated to governmental uses, including military message traffic and data links? But the analogy could be pushed too far, as in the U.S.S.R. the military may have a claim on better facilities than individual Soviet citizens making telephone calls.

This leaves the question of Molniya 1S, the synchronous communications satellite in 24-hour orbit. The general-use link in such an orbit was to have been called Statsionar and to use international frequencies. Instead the only satellite positively known to be used for communications purposes is in the Molniya 1 series, and after the launch, nothing more has been said about its use. Did it fail, or is it part of a military system of communications?

C. GEODESY AND MAPPING

Geodesy is both a military and a civilian interest activity. The Russians correctly identify U.S. geodetic satellites as performing a mili-

tary function, and all three U.S. military services have flown such satellites. Military operations use large volumes of maps, and their grids must provide an accurate link and reference to places marked on the maps. Maps which might be accurate for one part of the world could not always be related to those in other parts of the world, especially across oceans and polar regions. This is occasioned in part because the Earth is anything but a wholly regular sphere. Defining the geoid (the Earth's surface) is a long range task with many observations and much computer time necessary to the process. As soon as the Russians and the Americans had ICBM's, this military need became urgent. It does little good to develop a missile which has an accuracy over great distance of a few meters, if the locations of potential targets may be off in relation to the missile launch site by as much as several kilometers.

The Soviet Union says it does geodesy from space, but it has not identified specific flights except for its indirect use of both Soviet and U.S. space payloads as sighting targets for some exercises in triangulation. Because the Russian military need is real, and they have not identified such flights, it suggests they apply their military secrecy rules to withhold such flight information, as well as the geodetic results. They are obviously mindful of the military use not only because of the implicit need for missile purposes: They also are thought to add distortions to published atlases of Soviet territories to throw off users of these data. We know they have deliberately to this day continued to publish the wrong coordinates for the Baykonur Cosmodrome.

It must also be stressed that scientific and civil uses of geodesy are so important that the United States has also operated unclassified programs in geodesy, and there is international sharing of many geodetic findings. The one-time urgent need for military data and the secrecy maintained about that collection effort has for the most part disappeared. Some of the scientific efforts require even greater accuracy, as for example to measure continental drift, or slippage along earthquake fault lines.

Geodetic work may be pursued by many means. Traditionally, it was a slow process of many years of sending out surveying parties who measured the sides of interlinked triangles from one mountain top or land mark to the next. Today satellites provide triangulation opportunities which can indeed link the grid patterns of the whole world. The United States has found useful developing and applying parallel systems for geodetic studies. Passive balloons at relatively high orbital positions permit sighting over great distances, at least from one island or even one continent to another. Various radio techniques of accurately tuned and calibrated signals are another means. On two Star Flash satellites in the Discoverer series a very intensive strobe light could be detected over great distances by ground stations which knew where and when to look. Some of these radio and strobe light signals not only involve pointing accuracies, but also precise time measurements now possible with the improved time standards which modern science has provided.

In some of the NASA, unclassified geodetic satellites, combinations of several of these techniques have been put into a single payload. In a sense the first geodetic satellite was Vanguard 1 which showed the

world to be slightly pear-shaped. The NASA geodetic work is well discussed in the open literature, and the logic of the different methods is such that probably the Russians also use radio signals, navigation satellites, strobe lights, and combinations of these devices for their geodetic work. Presumably their geodetic work results have kept pace with their military and scientific needs.

Because the Russians have not identified geodetic flights, this study will have to limit itself to selecting inferential candidate flights for this purpose.

The Russians have also acknowledged the use of satellites for mapping purposes, but likewise have not identified particular flights, so the program is presumably buried within the Kosmos family.

The United States has put together uncontrolled maps of surface features such as the mosaics constructured from Landsat pictures which cover all of the contiguous United States and Alaska. Individual areas have been shown in maplike form in photographs returned by Skylab, other manned flights, and the Landsats. If the United States has also done carefully controlled mapping tied to the geoid, with all the necessary rectification, such maps have not been made public.

The Soviet Union has released an absolute minimum of satellite pictures of any description taken of Earth—mostly a few fuzzy reproductions of general terrain and clouds, taken from the manned flights, some global views from Zond payloads, plus weather satellite views.

Hence if high quality mapping has been done by either country, its products have been held back by public information restrictions.

III. Navigation

While navigation help from satellites is likely to become a universal service for many classes of ships and aircraft, the early uses of such systems have been military, and the sponsorship of flights has been military. In the United States, the Transit system was developed by and for the Navy, becoming an essential element in the total Polaris submarine and missile system. Later Transit was withdrawn from public discussion during the period when the United States Department of Defense operated under the greatest restrictions on public information. It has reemerged as discussable today.

The Soviet navigation satellite system has been advertised by the Russians as in operation, but they have not identified any of the flights. It is almost certainly among the Kosmos flights. They have given no separate and distinctive name as they have to Meteor and Molniya. Because the Russians also have long range submarine launched missiles, they probably used their system also to support submarine operations, and by now may be using them more widely, as does the United States. One is encouraged in this interpretation of how Soviet navigation satellites were first used when one notes the Russian Yankee class nuclear-powered submarines carry sixteen launch tubes so closely aping the American Polaris and Poseidon classes.

Many proposed civil navigation systems discussed in the open literature involve an interaction two ways between the ships and aircraft being navigated and the satellites in space. Typically, the mobile

ship or aircraft sends a signal which is received by several satellites, and they relay the signal to a ground computer which compares signal differences, computes a position for the mobile ship or aircraft, and this position information is relayed back via a satellite to the mobile ship or plane. Such navigation systems not only have moderate costs for the mobile unit but also can serve to support traffic control purposes as well.

The early military navigation systems are different in concept from the system just described. In general it is better for the mobile ship to remain radio silent, not to disclose its position. Submarines in particular rely upon concealment, and at worst want to do no more than stick out of the water an unobtrusive receiving antenna to pick up satellite signals. The Transit system has been described as consisting of satellites in polar orbit which broadcast on 150 MHz and 400 MHz holding to these frequencies with great precision. The listening submarine or ship measures the Doppler shift of signals to determine the relative positions of listener and satellite. The satellite periodically gives an accurate and updated set of emphemerides for its own position. Then a computer on the listening vessel combines the Doppler shifts in the harmonic signals and the position information on the satellite (fed in by satellite ground tracking stations) to calculate the position of the listener. This permits accurate locations to within a very few meters. Such a system with its accuracy helps the submarine or other ship to navigate, and to keep an update on missile target locations. The trade press has reported that the same system can be used for tactical fire controllers in ground warfare as well. By using satellite navigation data and the same grids, a fire controller out of view of a gun battery can still give directions permitting the very accurate placement of artillery rounds on selected targets.

Although the Russians have not described their system, the same compelling circumstances have applied, and it is likely they have gone about the same technical route as the Americans. The U.S. system now has been declassified and made available to civilian users.

IV. Space Related Control Systems

A. Traffic Control

There is no evidence yet that the Russians have advanced to applying either their passive navigation system or any active system to traffic control. The general principles of an active control system were described under the section on navigation.

Other countries of the world are talking about both maritime and aviation systems which will give position information in the first generation, and then later permit traffic control, especially important both to such busy air corridors as the North Atlantic, and to sea corridors such as channels and approaches to major ports.

The Russians have acknowledged the importance of space technology to such systems in the future. It is not clear whether they will join at an early date in the civilian international systems being formed today, or whether they will earlier develop their own systems within their military services and then use the bargaining tools of hardware

and systems to gain a bigger place in any later international system. They have made reference to a traffic control system which would use 24 satellites properly deployed.

B. MILITARY COMMAND AND CONTROL

Although the word "control" appears in this heading, the needs and functions are somewhat different from what is entailed in traffic control. Command and control has always been a feature of mass military operations headed by a commander and staff. But development of systems to provide timely and reliable command and control has received great impetus since World War II. This is not the place to explore the history of general staffs or the systems by which missions, plans, and tasks were carried out in combined staffs and theaters of operations in World War II. The big postwar change was the absolute necessity for controlling the use of nuclear weapons. The concept was that when the strategic bomber fleets of one side took off to begin hostilities, early warning radars and other sources would alert the opposite forces to get airborne and start toward their targets of retaliation. If the enemy turned back, or the alert was a false alarm, then a fail-safe system was supposed to turn back the responding airborne forces. Such systems provided horrendous problems of achieving close to absolute reliability to prevent the unnecessary use of nuclear weapons. These problems were multiplied many-fold when the subsonic aircraft and even the supersonic aircraft were replaced by ballistic missiles. Instead of hours for verification, the theory was that any missiles in soft launch sites would have to be on their way before they were themselves destroyed in less than an hour after launch by the enemy and there would be many minutes less warning if the first alerts came from the ballistic missile early warning system (BMEWS) installations in Alaska, Greenland, and England rather than from sensors close to the enemy launch sites. The notion of sure commands, proper authentication, and high speed response could only be carried out with the aid of computers and carefully thought out systems. But in some cases, high speed was not the only need. If a Moscow or a Washington were to be obliterated through missile attack, it might be necessary to have the necessary second strike kind of information travel to hardened silos and to hidden submarines in many oceans, regardless of what happened to the normal command structure. This suggested to military planners a place for space communications specialized for these command and control purposes. It also raised many issues which go beyond civilian communications satellite needs. Essentially, the added need was survivability. This might be achieved by hiding the satellites in high orbits where they were harder to locate and track especially if given the right radar-absorbing exteriors. It might also involve heavy shielding against radiation. It might involve use of wider frequency bands not to carry many channels of messages simultaneously, but the few key messages certainly, dodging around normal electronic countermeasures such as jamming. It might involve having many satellites so that some would survive even if others were destroyed. Command and control systems rarely rely

upon any single link, since the basic concept must remain functional if all the rest of the investment in expensive weapons is to pay off in believable deterrence, or, in the ultimate, in successful combat. Presumably the U.S. Navy's continuing interest in Project Sanguine, an extensive long wave, low frequency broadcasting system that would reach submarines completely under water is symptomatic of the need to have alternative channels of communication.

The exact nature of command and control systems is highly protected by security in any country, lest an enemy try to overcome it or to spoof it with false signals. Hence, we cannot expect the Russians to disclose what is the extent and the technology of their command and control system, which probably uses space for part of it. Presumably the Molniya 1 or other Molniya satellites provide the most obvious link, but would not be enough. Whatever more protected systems exist presumably would use encrypted messages, perhaps buried in other traffic to be non-conspicuous, or they might be sent on unusual frequencies less likely to be as easily monitored. They might use highly directional signals to minimize interception. These might come in short bursts to minimize the chance of monitoring. All these techniques are well known from articles in the international literature. In essence, the big difference is that ordinary traffic moves in large volume whether in plain language or encrypted, and if changing levels of activity are to be hidden, then dummy traffic is used regularly to disguise the real rising and falling of activity. By contrast, command and control traffic tends to be quite brief, but must be instantly recognized and understood by its intended recipients, to whom it is covertly or securely addressed.

Again, in the absence of any Soviet publicity, this study can only make some inferential guesses about command and control satellites in the Soviet military space stable.

C. OTHER SECURE SYSTEMS

In the summer of 1975, hints had begun to appear that the Russians have other data relay systems of a covert nature. *Newsweek* magazine reported that the Russians have buried special detection equipment near U.S. military bases, including SAC Headquarters at Omaha which broadcast their data to passing Soviet satellites.[10] Another story appearing in newspapers said the mysterious *Glomar Explorer* which earlier brought up part of a Soviet submarine from the mid-Pacific is now assigned to locating and removing Soviet sensors placed on the ocean bottom around California missile development centers. If these stories are inspired by real facts rather than being inventions, then we should be looking for any signs of supporting satellites in the Soviet program. One cannot expect them to be identified for us by the Russians. It is possible that a relatively secure system of space communications could be constructed which would collect and store signals from clandestine sources, whether these were remote, automatic devices, or live espionage agents, and then dump these findings by narrow beam to collection stations in the interior of the U.S.S.R.

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[10] Newsweek, New York, September 8, 1975, pp. 19–21.

V. Electronic Ferreting or Elint Space Missions

The Soviet Government has long had a reputation for giving special attention to the gathering of elint (electronic intelligence), also referred to ferreting, or sigint (signal intelligence), comint (communications intelligence), and radint (radar intelligence). In basic definition, all spacecraft which receive and report on electromagnetic radiation are performing the same basic task, whether that is for purposes of solar studies, astronomy, weather reporting, Earth resources work, communications, or weather reporting. Electromagnetic radiation varies in frequency or wavelength, in strength for natural reasons and may be modulated deliberately in amplitude or in frequency by man. It ranges from gamma radiation of very short waves and high frequency, to X-rays, to ultraviolet, to visible light, to infrared, to radio frequencies of many kinds, to very long waves of low frequency. The kinds of detectors and the classification or use of that information differ from one satellite to another, and whether the signals are relayed in analog form or first converted to digital form, and whether various forms of sampling or other processing are necessary.

It is still useful, however, to sort out categories of difference in origin and use of these signals. Some data are part of the natural environment, and these may obscure the receipt and recognition of a second major group of signals. The latter are those generated by man-made activities. In turn, the man-made signals or emissions fall into two major subgroups: (a) those directed toward space deliberately to be picked up and relayed by satellite, and hence supporting the function of communications satellites as part of a cooperative system; (b) those not intended to be picked up by the receiving satellites, such as private messages, or inadvertent leakages of signals, and hence supporting the function of elint, radint, comint and related categories.

Military interests extend to all natural phenomena, partly to understand the difference between natural signals and those which are man-made, and partly because many natural emissions, such as reflected light or radiated heat, translate into pictures and data of use to defining ground activity or airborne and space activity. But those emissions which were generated by electronic devices such as radio stations, radar equipment, microwave towers, and other spacecraft give us a general category of signals whose frequencies, power level, location, direction, and times of emission may answer questions of military interest. Although detection of the signals presents technical challenges, understanding the signals after their capture may be an even bigger challenge. For example, if the signals seem to be verbal, can the signals be read as a known language, or have they been encrypted in some fashion through use of a cipher or code? If they are the output of a radar set, what is the exact nature of those signals and their ability to discriminate targets under what conditions? Recent newspaper accounts have said that today even the inadvertent signal emissions of an electric typewriter may be capturable beyond the building where the machine is in use, and those indirect signals translated back into the text of the message being typed. Now it is probably unlikely that typewriter signals can be found in space in attenuated form because they would be overwhelmed by other background "noise" or the jumble

of other signals. Even when signals can be understood, the sheer volume presents large problems of selecting which to single out for preservation and study.

Soviet interest in elint or ferreting—the capture of communications signals and of radar signals as two examples—is evident in such activities as the trawlers manned by Soviet crews in civilian-type clothes who follow NATO naval maneuvers, attend missile launchings and recovery areas, or cruise off our coasts, with a forest of antennas on their craft. Soviet craft loiter near Holy Loch, Guam, and Rota. Soviet military writings also show a keen awareness of the importance of signal discipline to minimize the capture of their own emissions by others. Since their trawlers, their overt naval vessels, their embassies, and their air and space defense systems all engage in signal gathering, we have to assume they also gather signals by spacecraft which then are relayed either in real time or taped for delayed rebroadcast to analytical centers in the Soviet Union. Such activities are not judged here as to their moral value; they presumably are of practical use since such a large collection effort has been maintained for so many years. Hence this study will look for signs of space elint or ferret payloads.

VI. Minor Missions in Space for the Military

The United States space program authorities in the Department of Defense regard as non-sensitive some kinds of supportive space flight activity which improves military capabilities. For example, even when the public information flow has been generally restricted, details on some types of multiple payloads were still being released. Among such announced U.S. military payloads are a variety of calibration devices of different shapes, sizes, and materials. Also, there have been hardware elements such as gravity stabilization experiments, and payloads of different densities to measure rates of decay from orbit due to air friction. There have been tests of solar cells and of structures, and of small thrusters.

Hence, one should expect to find somewhere within the Soviet program counterpart devices carried by flights, since the same kinds of technological problems are faced.

VII. Early Warning Military Satellites

A special kind of detection satellite which senses and transmits electromagnetic signals is the early warning class for either nuclear explosions or missile launchings. These functions could be combined.

The United States over several years launched a number of Vela Hotel payloads which were put at a high circular orbit about 100,000 kilometers above the surface. They were calibrated to look for the kinds of frequencies associated with the initial burst of radiation from nuclear explosions such as gamma rays, neutrons, or infrared, whether occurring at the surface, in the atmosphere, or in space. They also kept track of solar and other sources of similar radiation, so that they could recognize the difference between natural phenomena and those triggered by men.

The United States also started a series of Midas flights which were in about 3,500 kilometer circular orbit above the Earth to watch for

the infrared signals of rocket exhausts as launches rose from the Earth, particularly above clouds. Later, several other classes of U.S. warning satellites were put up at about 36,000 kilometers circular and synchronous orbit, either over the Equator, or inclined so as to trace a figure-8 pattern near a particular longitude. Some of these payloads were pictured as having an angled sensor system. Presumably such payloads keep watch not only on Eurasia where missile launching silos are located, but on ocean areas which might be the sites for submarine-launched missiles as well.

One assumes that data in various parts of the electromagnetic spectrum as appropriate to what is being watched for are scanned and sensed by these satellites, with results transmitted in such a form that computers can distinguish between spurious signals and the kind guarded against, and that data also permit the rapid calculation of trajectories in the case of missile or space launchings. If so, such signals may give close to instantaneous warning of new launchings or of nuclear explosions, and this information constitutes in some cases an earlier warning than might be developed through a BMEWS radar or a seismic or acoustic wave sensor.

Since U.S. interest has been translated into flight hardware, one assumes the Soviet Union has similar protective interests and has examined these technical possibilities and perhaps put such satellites into service. This would be consistent with their also heavy investment in air defense and missile defense systems on home territory.

VIII. Military Manned Space Missions

Even before Project Mercury received its go-ahead in the early days of NASA, there was a proposal for MISS (Man in Space Soonest) which the U.S. Air Force sponsored. Later, Dr. Walter Dornberger's concept which perhaps had its ancestry in the Eugen Sänger antipodal bomber was translated into the X–20 Dyna-Soar project. This evolved over some time into a reusable space glider to be launched by a Titan III launch vehicle as a demonstration of reusable ships handling the heat load of reentry by radiation rather than ablation or heat sinks, methods which had been used earlier. But in 1963, Dyna-Soar was cancelled, and replaced by the MOL or Manned Orbiting Laboratory. This was also to be launched by a variant of the Titan III. It would have had a modified Gemini for the recoverable capsule and a hatch cut through the heat shield to reach via air lock a long tank with the orbital work space for this military station. One excuse used for cancelling this project in 1969 was that it duplicated the NASA Skylab plan. This was probably true only to the extent that both programs were to find out how well men functioned during moderately long orbital stay times. But the nature of the orbits to be flown and the work to be performed was quite different. The United States elected during the 1960's and early 1970's not to have a separate military manned space program, after several false (and expensive) starts. Only minor experiments offered by the Department of Defense were accepted for incorporation in the broader framework of scientific and technological tests included in Gemini, Apollo, and Skylab. If the Department of Defense is to have a military manned space pro-

gram, it will be within the general structure of the Space Shuttle. The Shuttle is mostly being paid for by the NASA budget, but design considerations such as cross range on reentry were made flexible enough to be compatible with military requirements. Also, the Air Force will construct launch facilities at Vandenberg Air Force Base to come on stream after development flights at the Kennedy Space Center. Whether military pilots will conduct military operations with their copies of the Space Shuttle, or whether they will use it almost exclusively to launch and later to repair or retrieve other independent unmanned payloads remains to be seen. At the moment the Department of Defense is not even committed to buying Shuttles.

As other parts of this chapter and another chapter show, the Soviet Union probably has gone a different route in use of manned space flight for military purposes. But if this surmise is supported, it almost has to be developed inferentially rather than from any overt Soviet statement or direct evidence. Most of the missions which have been talked about as practical military tasks in space technologically are not that different from civilian missions. They may directly support observation, with an emphasis on search and close study of manmade facilities and human activities, rather than a study of natural resources of farms, forests, minerals, water supply, and oceans. The technology and operations of placing, calibrating, repairing, and retrieving particular data gathering experiments may not be so different between civilian and military tasking agencies.

IX. Recoverable Military Observation Flights

In the 1950's, the United States gave some publicity in the trade press and before Congress that it was going to develop space reconnaissance systems of satellites which might survey the world photographically, and then permit the recovery of the resulting films on Earth. There was also talk of television pictures to give a first look. The principal one of these projects had several names—Big Brother, Pied Piper, Sentry, WS–117L, and Samos. Samos made some early test flights with rather uncertain results and obvious failures before it disappeared in 1961 under the blanket of rules limiting public information. A somewhat larger technology program which involved similar efforts of picture taking and recovery was called Discoverer, and the air snatching or the sea pickup of film-carrying recovery capsules was a regular feature of the news, until after Discoverer 38, when the name and activities, if any, disappeared in 1962 from official press releases and public testimony before Congress.

Since that time, the United States has made many military flights of unannounced purpose, but to this day will not describe on the record in public the purpose or the results of these registered but unnamed, unidentified flights. The United States and the Soviet Union in Strategic Arms Limitation Treaty (SALT) talks do refer in their agreements to "national technical means" as a way of gathering information for each to insure compliance by the other to any agreements made. Annual posture statements before Congress by officials of the Department of Defense carry the implication that the United States has a good handle on the problem of keeping track of Soviet

missile and ship construction and building of silos, and even of flights and tests. The "national technical means", not specified, may be made up of many kinds of sensors and sources of information, and this report will not try to deduce or define what all of these may be.

The Soviet Union also has "national technical means" at its disposal, and it is a fair inference that these means include a strong program of surveillance from space, with recovery of photographic film a part of the larger whole. One can imagine many connections in technology, even of actual flight hardware as well as launch vehicles, between the Vostok, Voskhod, and Soyuz programs, and what is done for unmanned military observation purposes. The technology shared may include not only use of the A–1 and A–2 launch vehicles, but possibly even the same basic spacecraft structures. At the least, the experience of building stabilization, communications, power, recovery and instrumentation systems must have worked back and forth between the manned, open programs and the unmanned, unacknowledged military programs.

Before 1962, almost all Soviet references to use of military photographic satellites were hostile, although lead times are such that they surely must have invested some years in development work toward their own systems of this class. After such Soviet flights began, there continued a Soviet public official stance of innocence with regard to their own activities, and disapproval of U.S. flights which they believed were taking place. However, on at least two occasions some years ago in private conversations, there were informal high level probes into the possibility of exchanging picture information gained from space. Former Senator William Benton was asked whether the two countries could trade pictures. Both Khrushchev and his son-in-law made half-jocular, half-serious offers, with no U.S. response. The issue seems not to have come up again. What is significant is that for some years the one-time virulent campaign against purported U.S. space observation activities has been almost completely muted.

Even as long ago as 1967, Professor Kondrat'yev discussed in nonmilitary terms the importance of understanding atmospheric optics as essential to successful reconnaissance. Although he talked to some extent about Earth resources work, his emphasis was upon high precision pictures.[11]

There appeared in 1968 a Soviet review of what were believed to be current and projected U.S. plans for military observation satellites, and whether accurate or not, it was written in factual terms without editorializing or diatribes.[12]

On the occasion of the 300th Kosmos satellite, another article reviewed the usefulness of such satellites for the most detailed reporting on both natural conditions and man-governed activities. Although the discussion was cast in economic terms, it claimed capabilities as already existing to do the most detailed synoptic measures on all activity on the Earth.[13]

With or without explicit acknowledgment, analysis to follow will demonstrate beyond all reasonable doubt that the Soviet Union flies

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[11] Kondrat'yev, K. Ya. Earthly concerns of the cosmos, Komsomol'skaya Pravda, Moscow, December 23, 1967, p. 4.

[12] Khozin, Major G. Second generation of space spies. Aviatsiya i Kosmonavtika, Moscow, No. 7, 1968, pp. 91–92.

[13] Borisov, T. Space reconnaissance. Trud, Moscow, September 25, 1969, p. 3.

the largest number of such military photographic payloads of any nation. (For example, a larger number of these Soviet missions than the second most active space operating nation has flights in its total space program, civil and military—the United States.) There is no reason to suppose, given the high priority these satellites evidently enjoy, that the Russians are not getting back a dividend they believe makes the flights worth their cost. On at least two occasions, there have been suggestions to the United States that it use similar payloads rather than U–2 aircraft. Khrushchev suggested them as the way for the United States to surveil Cuba after an American aircraft was shot down by a missile over Cuba. More recently, the Russians suggested satellites as a better way to check on missile defenses near the Suez than to use aircraft. But at the same time, they have charged that satellite pictures have been passed by the United States to Israeli military authorities.[14]

In summary, one application of space technology is to collect electromagnetic radiation emitted or reflected from the Earth. When this is done at lowest resolution and from fairly high altitude, the results are thought of as primarily of use for reporting weather, with such data usually in the visible or infrared range. When done at intermediate altitude and with somewhat higher resolution, and often in many parts of the spectrum, such results feed the growing experimentation with Earth resources evaluation and management. When the flights are done at the lowest sustainable altitudes and presumably in still higher resolutions, the resulting data reveal human activities in considerable detail. Wavelengths of visible light are the most obvious of interest, because of the well developed state of the art with photographic film able to accept vast amounts of data on small pieces of film which can be magnified for closer study. But selection of different sensitivities to various frequencies both in the range of visible light and beyond into infrared and ultraviolet, and use of color film all may extend the analytical opportunities. Here we find an area of application which blends together what is happening in Earth resources work and in military studies. For example, lower resolution multispectral work may reveal geologic and tectonic features which are not otherwise apparent. But as one moves into detailed study of agricultural crops and forests, with an interest in crop kinds and their health plot by plot, or marking trees which may be diseased, the resolution requirement becomes more severe. The same is true in use of Earth resources satellites for application in urban land use studies. The task of measuring the economic status of housing or spotting those houses which have insufficient insulation in winter through their infrared signatures begins to be a technology not wholly distinguishable from what military users of space data might require. Photography in the visible range would reveal the gross outlines of major human activities on the ground, whether construction, or order of battle on placement of missiles, aircraft, tanks, and trucks. But one can also imagine it would be useful in some cases to couple what seems to be true in a photograph with synoptic data taken at other frequencies. For example, what appears to be an undisturbed forest in visible light might show in

[14] Moscow Radio, July 14, 1970, 1900 GMT.

other frequencies that there was camouflage hiding activities, or that heat emissions disclosed what buildings were in use or unoccupied. Perhaps there could even be some spectral studies of exhaust smoke from a factory that would tell what materials were being processed in the furnaces. What shows up in stereo pairs may be much more revealing than single flat views. Basically, however, one supposes that the principal collection of data is possible only when there are no clouds interposed between satellite and the ground to be observed.

X. Ocean Surveillance

There are some frequencies of the electromagnetic spectrum which will penetrate cloud cover. In the Earth resources area, passive microwave affords one such opportunity. It is not clear whether resolutions are such as to give data beyond the level of climate and soil conditions to anything of military usefulness like order of battle.

One of the interesting exercises in which long range aircraft of the Soviet Union have engaged is that of locating U.S. carrier task forces at sea. The press long carried pictures of Bear turboprops with eight contrarotating propellers flying in mid-Atlantic or mid-Pacific, often with an escort of U.S. carrier aircraft or Royal Air Force planes flying alongside taking pictures in turn. In general, one assumes, the Soviet task of locating U.S. ships which may carry a strike capability with nuclear weapons is easier if the weather is good and if the U.S. ships are revealing their presence by carrying on regular radio communications, permitting radio direction finding. Acoustic signals of propeller sounds in the water are used also for ship locating even over great distances, and are especially important in monitoring submarine activities since the latter if nuclear powered may not surface for long periods and may practice tight radio security.

We must assume the Russians would have a strong motive to develop a technology to locate U.S. naval vessels at sea even when they maneuver to stay under cloud cover and when they keep their radio transmitters and radar sets turned off. An obvious approach would be to put into space radar equipment capable of making rapid wide area searches in any weather. However, providing a sufficient power supply and providing a system which will both do wide area searches and also detail what has been found with a signature which can be interpreted is no small challenge. Some technicians would say that such a capability is not within the state of the art.

However, there is now testimony before Congress on the public record which says the Soviet Union does have a radar system in satellites for ocean surveillance purposes, and from the few facts which have been given, it will be possible in the analysis to follow to identify those Soviet flights which fall into this category of activity.

XI. Fractional Orbit Bombardment System Satellites

This study is not directly concerned with military missiles beyond their use as launch vehicles in the space program and as the use of their navigation, guidance and reentry technologies may be applied to space systems as well. But there is one area in which military missiles and spacecraft come together: that of the fractional orbit bombardment system satellites—known as FOBS.

Every long range ballistic missile flight is really a space flight. The missile is given sufficient velocity during initial firing to carry it out of the atmosphere, often flying higher than low orbit satellites, to gain the speed without the friction of the atmosphere, and without the disturbances of winds throughout most of the flight before arrival at target. The path followed is that dictated by the same laws of celestial mechanics as govern space flights. The orbital path flown is one which intersects the Earth, thus terminating the flight. Such missiles fly a great circle path above the Earth on their way from the launch site to the intended target. There may or may not be some terminal guidance as the destination is approached. But essentially, if one knows the location of the launch site for a missile and what its intended target would be, the path it will follow can be known years in advance. (New MARV missiles would add complexities, however. The acronym refers to "maneuvering reentry vehicles" able to evade defensive missiles by changing course.) It was to this end that the BMEWS (ballistic missile early warning) system was constructed in Clear, Alaska; Thule, Greenland; and Fylingdales, England to fan out radar signals which would intercept at the earliest practical time the flight of missiles from the Soviet Union against the United States, Canada, and parts of Western Europe.

It is understandable that the Russians to increase the credibility of their forces would look for ways to thwart vulnerability, early warning, and predictability on the U.S. and NATO side. One way was to protect their own launch sites by hardening them in silos. Another was to consider the possibility of adding mobility to the launchers. A third was to shift from a land system to an ocean-based system by building ballistic missile submarines.

There are other opportunities as well. Changes in the simple orbital path is one. Instead of flying to a high point, which gives maximum warning to waiting defensive radars watching for anything to come over the horizon, it is also possible to fly a depressed trajectory to delay the time before radars will pick them up. This requires an orbital adjustment to hold down the apogee of the orbit and to steer the flight downward again as the target is approached.

As such flights go greater and greater distances, ultimately the point is reached where the initial thrust is sufficient to push the missile into orbit. As it falls back it is going far enough and fast enough that it "falls" around the curvature of the Earth, and does not intersect the Earth. It is then in orbit and will stay there either until air drag finally pulls it to "decay", or until a retrorocket is fired to brake it to a commanded reentry.

The opportunity to send a rocket at global distances provides new military options. Such a rocket can make a direct great circle flight to its target with a depressed trajectory to minimize early warning. Or it can fly the long way around the world on the other part of a great circle path to arrive at its target in exactly the opposite direction from which the principal defending radars have been pointed. For example, if the big defense radars are in the Arctic, and the missile comes to a U.S. target by way of Antarctica, that main defense system would miss it.

And there is still a further step which can be considered in any tabulation of options: Instead of having a missile called down short

of one orbit, it might be placed in a sustained orbit and called down from orbit only when hostilities were to begin. This possibility will be discussed later in greater detail.

XII. Military Interceptor/Inspector/Destructor Satellites

The record shows that particularly in the early years there was a Soviet hostility to all military flights operated by or attributed to the United States, whether these were for purposes of communication, weather reporting, navigation, early warning, or observation. At times, the Soviet authorities accused the United States also of plotting to put weapons in orbit, an activity subsequently banned by treaty.

One can imagine that Soviet military planners would see as a necessary ingredient in any stable of military space systems an ability to identify what the United States was really up to in space, and to have the option of destroying that payload if need be. Such actions could be motivated either by defensive considerations such as to neutralize bombs, or as aggressive by blinding the eyes which might be used by the United States to give it warning of changes in Soviet order of battle, or navigation for U.S. submarines, or post damage assessment if the two nations had come to a partial use of their weapons in a nuclear exchange.

The United States at one time put funding support into a project called Saint which was to have the capability of inspecting satellites whose missions were unknown. The project was later terminated before any flights were made. The kinds of questions raised included political: How would another nation react to having a U.S. payload go into a co-orbit with one of theirs? Would we really be able to judge the full function of the unknown satellite by a study of its configuration, its antenna lengths, its behavior? Could we determine whether it had a weapon on board either from its inertial mass if nudged or its reaction to a neutron pulse sent its way? If we were to consider direct interference with the unknown payload by painting its lenses, or breaking its antennas, or attaching extra propulsion to send it elsewhere, what would be the reactions of its owners? What if it were booby trapped in some fashion? The questions are multiple, and one then weighs the possible advantages of an inspector system which coorbits against other options such as better sensors on Earth, or vertical probe inspectors which might or might not be able to make a surreptitious inspection in a remote part of the world without having to coorbit with the satellite.

In any case, the United States withdrew from construction of hardware, while in the Soviet program, actual flight tests of an inspection system have been conducted.

XIII. Ground Based Space Detection and Defense Systems

When space-based inspection systems either do not exist or fall short in some fashion of meeting all needs, ground based systems are the alternative. The United States not only has tracking systems for its own spacecraft, but has acknowledged a variety of other sensors which more generally keep track of what is in orbit. One system is that estab-

lished by the Navy as SPASUR, also called the Dark Fence. It was strung in a line at a fixed latitude across the tier of southern States from Georgia to California. Several radio stations send out a fan shaped signal in CW (continuous wave) which then would be reflected back to Earth by any satellite, no matter how uncooperative, passing through the fan. Radio receiving stations are also spaced along the same latitude. By sending any reflected signals to a computer at Dahlgren, Virginia, it calculates the location of the passing satellite, and adds the data to its memory bank. Successive passes through the fan establish the presumed orbit of the satellite. The computer remembers what should be coming through the fan, and any new object or any object displaced from its estimated path sounds an alarm and is a signal to analysts to gather more data until the unexplained "blip" can be accounted for.

A second method for finding uncooperative satellites is through radar, such as the ones already described as making up the BMEWS system. In addition to those three there are other radars intended specifically to keep track of space objects. The exact number and location of such is not in the public domain. One is clearly visible to motorists on the New Jersey Turn Pike because of its large radome near Morristown. Others are known to be on Shemya in the Aleutian Islands, and in Trinidad. At Eglin Air Force Base in Florida is a large phased array radar which uses electronic rather than mechanical scanning of the sky. Especially since the 1975 difficulties with Turkey, public attention has been drawn to the U.S. radars in that country which could watch some Soviet launchings. The British have a large station at Malvern in England. A good radar not only can observe blips, but with some discrimination and good computer support can reach conclusions about the shape and dimensions of space objects, although presumably the answers are not definitive when some radar absorbing materials might make an object seem smaller than it really is, and adding corner reflectors might make it seem larger.

A third approach is through optical devices. Tracking cameras of high sensitivity and wide fields of vision were introduced in some instances fairly early in the U.S. program. These capabilities have been enhanced over the years at Cloudcroft, New Mexico, and in Hawaii to get enough resolution to see something of the target satellite.

Since all of these U.S. systems have had repeated publicity, and Soviet needs are similar, one can assume they have examined all these techniques. We know they follow their own space probes to distances as great as 250,000 kilometers and more through use of electronic enhancement of optical signals. We also know they have long been active in development and deployment of radars. Their purported state of development was described in detail by a pair of articles in *Aviation Week*.[15] This study reflects a high level of Soviet technology.

There is even less information in the public domain about the location of its space surveillance radars than about corresponding U.S. stations. In the early days, the Soviet Union encouraged people

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[15] Miller, Barry. Soviet radar expertise expands. Aviation Week, New York, February 15, 1971, pp. 14–16: ———, Soviet radars disclose clues to doctrine. Aviation Week, February 22,1971, pp. 42–50.

to send in reports on satellite sightings to a central point in Moscow. They published statistical tables on sightings, and these covered not only Soviet satellites, but some U.S. ones as well. Most of the early equipment pictured was relatively simple, but they had a few models that in their pictures resembled the Baker-Nunn cameras of high capability used in the United States. Most of their optical findings went into studies on atmospheric drag and irregularities in the gravity pull of Earth.

It is also known that the Russians have an optical tracking station in Cuba, and this would serve not only scientific purposes, but could be used to keep track of some U.S. space activities. Launches both at Cape Canaveral and Vandenberg have been monitored by Soviet ships.

A capability to operate an ABM (antiballistic missile) system implies a good tracking system. The Russians have deployed the Galosh ABM system around Moscow, and presumably they keep it exercised by passing spacecraft, including designed calibration payloads. Such a system typically incorporates a wide area search or early warning system as well as terminal guidance needed for intercept. If the Russians are capable of finding large numbers of incoming missiles and intercepting them outside the atmosphere, then they almost surely have the same capability for picking off at least the low-flying space payloads.

Presumably some similar capability resides in the U.S. ABM system which protects some of our Minuteman sites in North Dakota. But the United States also has had two other space defense sites in the past. One was based on Johnston Island, and the other at Kwajalein Island, both in the Pacific. These sites like any fixed ground site can operate only when the passing satellite is within the range of the particular intercepting missile available to the defender. This means that only on certain orbits would it be possible to pick off a satellite selected for destruction. Khrushchev once said that the Russians were capable of hitting a fly in outer space. While these were figurative terms, he probably was talking about the ability of the Galosh system to hit either a missile warhead or a satellite.

Congressional testimony of the U.S. Department of Defense indicates the Russians have a large missile (and space) defense development center at Sary Shagan. Missiles launched from some other site such at Kapustin Yar can be picked up by the radars and the intercepting missiles of Sary Shagan. This flight range was identified by *Aviation Week* in the mid-1950's, so has long been known.[16]

To date, there is no known record of a Soviet inspector satellite flying a co-orbit with a United States payload, and there is no known case of a ground-based Soviet rocket interceptor being used against a United States payload. In similar fashion, there is no evidence of U.S. interference with a Soviet payload by co-orbit or by ground based rocket interception.

Aviation Week in late 1975 broke a story that the Russians were suspected of using laser weapons to blind the infrared (IR) sensors in U.S. early warning satellites. According to the story which had

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[16] See Aviation Week, New York, November 25, 1974, pp. 20–21, for Landsat picture of Sary Shagan.

origins in the Pentagon, the sensors were not permanently blinded, but for periods of time up to four hours were neutralized. This happened from October 18 on three times to 24-hour synchronous satellites and twice to 12-hour semi-synchronous satellites. The story said the intensity of the phenomenon was from 10 to 1,000 times that of a forest fire or volcano, and that no weather satellite had found any natural source for these events. The frequency of the signal was like that to be expected of a hydrogen-fluorine laser. The signals had come from the western part of the U.S.S.R. The suggestion was that if the source was from lasers, then the intensity that might be expected if used against low-flying U.S. missions would reach levels 50,000 times as high. The United States since the early 1960's has probed Soviet satellites with lasers from Maui, Hawaii, and Cloudcroft, New Mexico, to determine lens and film types used in Soviet photographic missions, but not in a manner to cause deliberate damage to such Soviet satellites.[17]

This suspicion, if borne out, would have been of enormous consequence to detente, the SALT talks, and the military positions of the two countries, so naturally raised many public questions. Secretary of Defense Rumsfeld responded to these, saying that investigations were continuing, but that the preliminary findings were that major gas pipeline explosions had caused these signals. He said known explosions and fires from over-pressurizing a major gas line correlated well with the satellite data, and he reviewed the U.S. use of laser probing of Soviet satellites.

It may be too early to close the book on these incidents, because it seems strange that gas fires which have been observed many times before have not previously had this same effect on satellites. If it was the intensity of these particular fires, then this experience may help to calibrate and interpret future signals received by satellites in what is clearly an evolving technology.[18]

XIV. Orbital Bombs Stationed in Space

Space writers and staff studies have explored the possibility of stationing bombs in orbit. Such an operation is now outlawed by treaty, and there is no real likelihood that any weapons of mass destruction are in orbit. Before such activities were banned, and while such activities might have been contemplated, it is not likely that technology had yet reached the place where such stationing could be carried out. The question of whether there were any developmental flights of the basic hardware is one which will be assessed later in this chapter. It may be helpful to discuss the subject for some perspectives on the issue. Setting aside the matter of the treaty for the moment, and looking at the kind of proposals which have been made in the past one can reach some conclusions.

In assessing the merits if any and the drawbacks which are considerable of any orbital bomb system, one must recognize that technology is not stationary, and what may be the right answer today on technological feasibility may be different tomorrow. For example, in some future age, one might imagine a highly developed ability to travel

[17] Aviation Week, New York, December 8, 1975, p. 12ff.
[18] Aviation Week, New York, January 5, 1976, p. 18.

with ease throughout the solar system, and some kind of future cosmic chess game where mankind somehow still had national rivalries and weapons of mass destruction, but had arrived at a situation where the ultimate confrontation would take place many millions of miles from Earth, with both contenders realizing that the battle of the space fleets would also settle the future of Earth—that is, the surviving space fleet would be in a position to dictate the terms on which the conflict would end. This is not possible today, and few people would like to see human efforts pointed that way when a different effort might solve the problems of the arms race.

One can speak only in terms of current capabilities and currently attainable systems. Technically a bomb can be placed in orbit, but that is not to say that it is practical. If only one bomb or a very few bombs were to be placed in orbit, their presence might be kept secret or disguised. But such an action would have limited military effectiveness. If the fact were advertised as a form of threat or blackmail, the launching state would run high risks of counter moves including a preemptive strike, and no responsible power really acts as if nuclear exchanges were a rational policy. Several states feel tied to a policy of credible deterrence, but not to nuclear war as an active policy. A nation threatened by a bomb in orbit might surrender if it felt powerless, but most states have client relationships with other states, and the ultimate consequences could be too unpredictable to have such a threat an effective policy.

Suppose that a space operating nation decided that instead of a few secret weapons or a few for blackmail purposes, it was going to go all out with an effective fleet of bombs in orbit that might be sufficient to overcome another super power, including its second strike capability. This is not really feasible, either. There are many kinds of sensors and many analytical techniques available to both U.S. and Soviet defense authorities which should start the alarm bells ringing long before such an operation could be completed. Although the aggressor might hope for enough indecision on the part of the intended victim that a sufficiently large force could be deployed in orbit to be decisive, the aggressor might also find that he had telegraphed his punch, and this would lead to a preemptive strike against him. This would be a very large risk on the basis of psychological profiles of political leaders or administrative studies on command and control.

Beyond the issues of war-gaming and possible responses with the most extreme consequences, there are other problems. Developing such a system to attain operational status would take time, and most development plans themselves have tell-tale signs that might provoke either a matching effort or loud public complaints and marshaling of world opinion. Such new systems do not spring full-blown. Their extended testing requires many trial flights loaded with diagnostic telemetry which may reveal something of the purposes. When the flights continue without telemetry, one suspects the operational phase has been reached.

Suppose that a nation decided it was ready to put actual nuclear weapons in sustained orbit. Not only is there the question of whether they might be detected and neutralized directly or outflanked by some counter move; there is also the question of what happens when the

orbit decays. Would the nuclear material be lost? Would it pollute the atmosphere? How long would the orbital bomb remain reliable, and what fail-safe devices would insure that it did not go off when it returned to Earth? How effective would command and control be over such payloads? Could signals be jammed or could spoofing be done? Suppose ultimate need to use such weapons developed: What assurance would there be that they were in the right orbits to strike their assigned targets in timely fashion? If designed as counterforce weapons, they would have to be ready to strike the ground weapons in a salvo effect or the other power might launch a return strike against the homeland of the aggressor. If such weapons were to be put up only in a gathering crisis, this would seem a rather powerful activating signal to the intended victim of the bombs. If such weapons were to be put up gradually over a period of time for use in some future year non-specific contingency, then the necessity for long term stability and reliability would carry problems.

Now one can also see the possibility of a space shuttle or its space tug retrieving such a bomb of another nation with all kinds of unpredictable consequences.

The general state of Soviet technology today would seem to preclude any early move to circumvent the treaty and to place bombs in orbit, as a practical danger. There are too many failures of hardware now, and too many payloads decay at random all over the world with the consequent risk of disclosure of what was going on, if nuclear material were on board a flight.

One hopes and expects the treaty banning such weapons will stay in force and be honored. Meanwhile both the primitive state of technology and the imponderables of countermoves with known weapons will likely discourage any major power from placing live weapons in orbit.

XV. Analysis of Soviet Flights to Discover the Military Component

An early chapter of this study discussed the reasons why the Russians apparently selected the overall cover label of Kosmos to account for 786 of their flights through 1975. Since the bulk of these flights are not explained by the Russians, one assumes that most of the military space activity (but not all of it) is contained within this label. The process of identifying Kosmos flights is one of fitting them into categories by launch site, launch vehicle, and kind of orbit. Then one eliminates the flights acknowledged in detail by the Russians and the flight failures signaled by debris launched at times of known windows for flights to the Moon or planets. The remainder then must be examined in the context of the kinds of military missions which have been discussed in general terms in sections of this chapter and test the hypotheses for consistency of fit.

Table 1–3 of Chapter One gave the kind of detailed breakdown into categories of launch vehicles and orbital inclinations from each launch site required for the building work which must be done next.

Tables 2–2, 2–3, and 2–4 of Chapter Two accounted for the Kosmos flights which have been described as to scientific experiments carried.

Although one can recognize the possibility of being spoofed, in general accepting the Soviet reports is reasonably safe. Genuine scientific payloads usually operate in telemetry modes which can be intercepted by Western stations, and the signals received can often be interpreted as to general purpose. The detailed published findings would be hard to invent and to keep consistent with the known times and locations of the flights when there may be U.S. or other nations' payloads gathering synoptic data at the same time.

The pattern which will be followed here is to take each known type of launch vehicle and to categorize its Kosmos flights by mission until all are accounted for, or until a small unknown remainder is left.

A. USE OF THE B–1 VEHICLE AT KAPUSTIN YAR AND PLESETSK

Although about 38 of the smallest of the Kosmos flights have now been followed by published scientific findings, a large number of such flights have been quite repetitive in nature as if they fulfilled an operational purpose, and no findings or other results have been published even with the passage of considerable time. These have to be viewed as probably military until the Russians produce evidence to the contrary. They would have no reason to be making purely scientific flights and withholding the evidence of this for such protracted periods.

1. Kapustin Yar

The B–1 class vehicle came into use in 1962 at Kapustin Yar, and all the early ones were given descriptions of their scientific missions and the results were published. The flight of Kosmos 31 was the first to be in the non-described category. It was one of 11, all of which had an apogee in the range of 478 to 616 kilometers, and a perigee in the range of 207 to 294 kilometers. Their inclination was at 49 degrees or close to that. A second series of 11 unexplained Kapustin Yar flights had generally higher apogees (1,154 to 2,186 kilometers) and generally lower perigees (219 to 225 kilometers). One launch was distinguished by its carrying two payloads. Many missions have been postulated for these smallest and simplest of Soviet space payloads. Most are spin stabilized. Presumably they physically resemble their publicized scientific counterparts in similar orbits, which use a short cylinder with hemispheric ends, and usually have solar cells to keep them functioning for some months or years. Based upon U.S. parallels, they would seem to be possible carriers of some kind of environmental sensors, or serving as radar calibration devices, or testing out components to be used in later, more complex missions. Nobody in the private sector of the West has caught decipherable telemetry and no analog data as might be used to gather weather data. So in a sense, these least significant payloads, in the roughly 400 kilogram class, are among the least known to the analyst working with open source materials. Based upon their dual nature, the pair put up as Kosmos 42 and 43 may have been a developmental flight for other multiple launch flights which followed with the larger C–1 vehicle.

2. Plesetsk

These Kapustin Yar flights all at 49 degrees or more recently 48.4 degrees are now a rarity, but they have their counterparts launched

from Plesetsk. The Plesetsk flights without published findings fall into three distinct subsets: those 51 at 71 degrees inclinations in low, eccentric orbit similar to the orbits flown earlier from Kapustin Yar, phased in at the new site in 1967 and phased out at the old site in 1968 and flown at the rate of 5 to 8 a year; a new subset of 10 with intermediate altitude apogees at the rate of one or two a year, beginning in 1968, also at 71 degrees; and a third subset with a high apogee at the rate of one or two a year beginning at the new site in 1968, phased out at the old site in 1972, but at 82 degrees. These Plesetsk flights like their earlier Kapustin Yar equivalents have to be classified as "minor military missions" in the absence of other explanations which will withstand the tests of consistency and logic.

It also seems fair to suggest that these are missions which are related within each of the selected subsets, because successor flights seem to be replacements on a regular cycle for those which went before. Those replaced most frequently are those in the lowest orbit because these are lost through simple decay in a period of a few months. For example, on October 1, 1975, those remaining in orbit from the entire table of 93 payloads were: the last four low eccentric flights from Plesetsk; the last three intermediate eccentric flights from Plesetsk; and the last high eccentric flight from Plesetsk, for a total of eight. The average life spans to decay of each category of flight of those which have decayed has run: Kapustin Yar low orbits: 152.5 days; Kapustin Yar high orbits: 414.4 days; Plesetsk low orbits: 139.7 days; Plesetsk intermediate orbits 383.6 days; and Plesetsk high orbits: 219.5 days.

3. Other B–1 Flights at Both Sites

The second table on B–1 flights merely restates in similar form to the first table the same kind of orbital data on scientific flights for comparison purposes. It should be remembered a number of these were indistinguishable from military flights until scientific findings were published about them well after the flights were over.

TABLE 6-1.—PROBABLE MILITARY SPACE FLIGHTS USING THE B-1 LAUNCH VEHICLE BY KOSMOS NUMBER, APOGEE, AND PERIGEE

Year	Kapustin Yar						Plesetsk								
	49° low orbit			49° high orbit			71° low orbit			71° medium orbit			82° high orbit		
	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee
1964	31	508	228	42–43	1,099	232									
	36	503	259												
1965	76	531	261	70	1,154	225									
	93	522	220												
	95	521	207												
	101	550	260												
1966	106	564	290	119	1,305	219									
	116	478	294												
	123	529	263												
1967	197	505	220	145	2,135	220	148	436	275						
				165	1,542	211	152	512	283						
				176	1,581	206	173	528	280						
							191	518	281						
1968	202	502	220	221	2,108	220	222	528	277	204	873	282	211	1,574	210
							242	440	280				233	1,545	210
							245	507	282						
							257	470	282						
1969				268	2,186	219	265	485	283	275	805	284	283	1,530	210
				307	2,178	220	277	494	280						
							285	518	279						
							295	500	282						
							303	492	282						
							308	422	281						
							311	496	284						
							314	491	282						
1970				347	2,073	223	324	492	283	372	855	279	319	1,537	209
							334	508	281	362	854	281	380	1,548	210
							351	494	282						
							357	500	282						
							369	534	278						
							388	532	281						
1971							393	512	283	391	828	277	408	1,542	211
							421	492	283	440	814	282			
							423	511	282						
							435	505	282						
							453	522	281						
							455	516	282						
							458	523	281						
							467	502	279						

TABLE 6-1.—PROBABLE MILITARY SPACE FLIGHTS USING THE B-1 LAUNCH VEHICLE BY KOSMOS NUMBER, APOGEE, AND PERIGEE—Continued

	Kapustin Yar						Plesetsk								
	49° low orbit			49° high orbit			71° low orbit			71° medium orbit			82° high orbit		
Year	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee
1972				501	2,149	222	485	506	280	497	812	282	472	1,568	207
							487	531	278						
							498	511	282						
							523	507	283						
							524	537	277						
							526	511	282						
1973							545	521	279	615	859	280	601	1,561	210
							553	519	282						
							558	526	279						
							562	510	282						
							580	518	283						
							608	528	281						
							611	507	280						
1974							633	516	280	*662	838	282			
							634	516	281						
							668	519	281						
							686	515	281						
							695	493	283						
1975							705	524	281	*750	830	281	703	1,545	207
							*725	508	283						
							*745	540	274						

NOTES

1. The table includes all B-1 launched flights which have not been given explanations in the scientific literature or the press and are presumed to be fulfilling military missions until proven otherwise.
2. The flights are grouped by years, by launchsite, by approximate inclination and by general category of apogee and perigee.
3. Apogee and perigee are given in kilometers.
4. As of Dec. 31, 1975, all of these flights have decayed from orbit except: Kosmos 662, 725, 745, and 750. These are marked with an asterisk in the table.

SOURCES: All data on the flights are from TASS bulletins as summarized in Appendix A of this study. The fact of decay is drawn from the Royal Aircraft Establishment (RAE) and Goddard reports on all objects in orbit, and as summarized also in Appendix A.

TABLE 6-2.—OTHER SPACE FLIGHTS USING THE B-1 LAUNCH VEHICLE BY KOSMOS NUMBER, APOGEE AND PERIGEE

Year	Kapustin Yar									Plesetsk					
	49° low orbit			49° medium orbit			49° high orbit			71° low orbit			82° low orbit		
	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee
1962	6	360	274	1	980	217	2	1, 546	212						
	8	604	256	3	720	229	5	1, 600	203						
				11	921	245									
1963	14	512	265	17	788	260									
	19	519	270												
	23	613	240												
1964	25	526	272												
	26	402	271												
	49	490	260												
	51	554	264												
1965							53	1, 192	227						
							97	2, 100	220						
1966	135	662	259	108	865	227	137	1, 720	230						
1967	149	297	248	196	887	225	142	1, 312	214						
	163	616	261												
	166	578	283												
1968	215	426	261	262	818	263	219	1, 770	222	261	670	217			
	225	530	257				259	1, 353	219						
	230	580	290												
1969	IK 1	640	260				IK 2	1, 200	206						
1970	320	342	240				IK 3	1, 327	207	321	507	289	356	600	240
	335	415	254							348	680	212			
	IK 4	668	263												
1971							IK 5	1, 200	205						
1972	IK 7	568	267							481	540	279			
										IK 8	679	214			
1973							IK 9	1, 551	202						

NOTES

1. This table includes all B-1 launched flights which have been given explanations in the scientific literature and/or the general press.
2. The flights are grouped by years, by launch site, by approximate inclination, and by general category of apogee and perigee.
3. Apogee and perigee are given in kilometers.
4. Interkosmos flights are grouped with Kosmos flights and are symbolized by the prefix IK.
5. As of December 31, 1975, all flights have decayed from orbit.

SOURCES: All data on the flights are from TASS bulletins as summarized in Appendix A of this study. The fact of decay is drawn from RAE and Goddard reports on all objects in orbit, as summarized also in Appendix A. References to the scientific missions of these flights were scattered over many years in many different Soviet scientific journals and in their COSPAR annual reports.

B. USE OF THE C–1 VEHICLE AT ALL THREE LAUNCH SITES

Because the C–1 vehicle is inherently more versatile than the B–1, having both a greater lift capacity and a restart capability for circularizing orbits, it is not strange that a greater variety of patterns of use have appeared, and pads have been built for launches at all three major sites. These conditions make a little more difficult the task of sorting out categories and missions, but what is possible is aided by the repetitive patterns which appear. See Table 6–3.

1. Tyuratam Development Flights

Tyuratam was used for development flights starting in 1964 and none has occurred there since 1968. At first they appeared as triplets and quintuplets, and finally as singletons. The first three launches of three payloads each were all in eccentric orbits with increasing apogees. The next three launches of five payloads each were put into circular orbits at increasingly high orbits. The final three launches each with only one payload were in fairly low circular orbits. Each of these sets of flights can be seen as potential developments for one or more operational systems which later appeared at Plesetsk. All the Tyuratam flights were at an inclination of 56 degrees.

2. Plesetsk Elint or Ferret Missions

Most of the follow-on Plesetsk flights have been at 74 degrees, with exceptions to be noted. The classes are so uniform and so sharply delineated one from the other it is no trick to place flights within classes. Assigning missions to some of these classes is harder. Those in lowest orbit, since 1967 and now appearing typically about four times a year, are circularized at about 550 kilometers. The last 8 of these 26 payloads were recently shown by Geoffrey Perry to be disposed in a regular pattern with their orbital planes at 45 degrees intervals.[19] As these are relatively long life orbits, replacements relate either to substitutions for failed instrumentation or are to extend the completeness of coverage. By a process of elimination and by comparison with some U.S. flights, these seem to be military elint or ferret flights. They seem to remain passive through that part of their flights outside the Soviet Union, and hence must be gathering rather than giving out information. There being so many of them and without published scientific findings, their role has to be military.

3. Plesetsk Navigation Missions

The second category of C–1 flights are those which flew in circular orbits at about 775 kilometers from 1967 to 1970, and then the series was replaced by a new group that flew at about 1,000 kilometers circular orbit. These flights came about twice a year, and the clarity and sharpness of the changeover showed that one program was replaced by the other. These flights at 74 degrees in turn came to an end in 1972. That year, almost identical flights appeared at 83 degrees inclination instead, and about four a year are put up.

This report has suggested that it should be possible to find within the Soviet program the navigation satellites which for many years

[19] G. E. Perry, private communication, September 6, 1975.

the Russians have said were flying but which they did not identify. It is now possible with high confidence to identify the main series of navigation flights. First of all, Geoffrey Perry has found that these flights fall into a regular pattern of orbital planes 60 degrees apart, providing the necessary global coverage, with replacements put up as earlier payloads' instrumentation fails. Second, the Kettering group have found that these satellites broadcast on the same frequencies as the American Transit navigation satellites—150 and 400 MHz. Third, Christopher Wood of the Kettering group has recently discovered within the telemetry from these satellites that the Russians broadcast time signals in hours, minutes and seconds, synchronized with the international standard and Moscow time, which is a further indication that these flights are almost certainly serving a navigation purpose.

The first shift of the flights from 775 kilometers to 1,000 kilometers would extend their range slightly. The next shift from 74 degrees inclination to 83 degrees extends coverage in polar regions, even though not flying at the 90 degrees favored by their American counterparts. Also, in the summer of 1975, Perry found that among the 83 degree navigation satellites even a fourth series has appeared. At first these seemed to be thrown in at random, but now they are filling in a similar grid pattern of orbital planes 60 degrees apart, as the third series, but these are offset by 20 degrees from the earlier set. What all of this seems to indicate is that the Soviet system has been evolving over a period of time with product and operational improvements.

It is amusing that a recent Soviet article explains in detail how to use the U.S. Navy's NNSS (Transit) system to determine ship positions, never mentioning that it is also a probable description of how to use the Soviet system as well. The article claims that when the look angles from ship to satellite fall in the elevation range of 26–66°, the accuracy of the system is 60–130 meters.[20]

4. An Unidentified Category at Plesetsk

When flights of the C–1 began at Plesetsk in 1967, these seemed to be a continuation of the single flights with which the Tyuratam series had closed in the years 1965–1968. These flights come once or twice a year at 74 degrees, and at a typical altitude of 825 kilometers circular. They do not fit the regular series of probable ferrets whose complete, low-flying network gives close to round-the-clock worldwide coverage. They do not give out the signals the navigation satellites now are known to broadcast. They seem to be passive in most of their travels across the globe, and apparently about one active at a time is sufficient to take care of whatever need is being fulfilled, with a replacement sent up only when instrumentation in an earlier one fails. Most guesses are that these relay some kind of data where real time transmittal is not urgent, or they would fly higher and would show up in greater numbers. This suggests among the earlier catalogued uses one of the store-dump systems for military or clandestine services use. This cannot be confirmed, but a process of elimination does not suggest much else.

5. A Plesetsk Series Which Could Add Geodesy to Navigation

Still another series of flights, most typically put up about twice a year fly at altitudes of about 1,200 kilometers circular orbit. These most

[20] Referativnyy Zhurnal 51 Astronomiya' Otdel'nyy Vypusk, No. 8, 1975, S.51.160.

closely resemble in their regular patterns and signal emissions the navigation series already discussed, except that these would seem in some fashion duplicative and surplus. One is reminded that navigation and geodesy are not easily separated as both need precise orbits, accurate timing signals. Both are capable of using Doppler shifts of frequencies carefully tuned to measure distances or pinpoint locations. If one had to decide which series was predominantly for navigation and which predominantly for geodesy, the choice would seem to be the ones appearing very frequently would serve a day-in, day-out navigation purpose. Those flying higher and less frequently would allow the linking of triangles over greater distances for building the geodetic grid defining the geoid. Hence, this series from 1968 to the present is considered the most likely candidate for a geodetic system. This would also account for some of the stray flights at similar altitudes but at other inclinations such as 83 degrees (Kosmos 480) and at 69.2 degrees (Kosmos 708). Using several inclinations often helps geodetic work.

6. Plesetsk Military Communications Possibly for Command and Control

The highest altitude flights of the C–1 are those that put up eight payloads at a time in circular orbits about 1,500 kilometers high. The trade press believes them to be military communications satellites. If so, it would seem they are of the store-dump type because they do not fly high enough to permit real time communications among all Soviet forces. These launches come two or three times a year, meaning even if their instrumentation fails that probably 24 to 30 or more are active at any one time. These would seem to come closest to providing a redundant route, limited number of channels, worldwide system such as might be needed for some kinds of military communications and command and control. The store-dump feature would not allow real time control of all missile forces, but it would allow passing of information to or from Soviet submarines and other organizations if time was moderately important but not demanding to the extent of being real time. The fact that we should be looking for military communications systems within the Kosmos family is strengthened by testimony before Congress by the Department of Defense that such systems exist beyond the Molniya, more open system. They could also be used on a real-time basis for tactical communications within a given theater of operations.

7. Plesetsk Targets for Interceptors

There is one other small class of C–1 flights different from all the rest whose mission can be established. These occurred in 1971, and perhaps in 1972 (Kosmos 521) when payloads were put up at several different altitudes, but all at 65.9 degrees inclination, later to become targets of F–1–m launched interceptors from Tyuratam. See comments below on Kosmos 752.

8. Plesetsk Minor Military C–1 Flights

Last of all among the C–1 military-related payloads are a very small remnant—Kosmos 660 at 83 degrees and Kosmos 687 at 74 degrees. With their eccentric orbits, they do not fit the regular military

series already described for the C–1, all of which are virtually in circular orbits. This eccentric orbit pair may turn out ultimately to be scientific, or, if no findings are published, they will end up in the category of "minor military". As will be shown presently, the C–1 probable ferrets are paralleled by a group of bigger probable ferrets put up by the A–1. Perhaps in similar fashion, the B–1 minor military category payloads are being upgraded to use of the C–1 part of the time, but this cannot be answered conclusively until enough time has passed to see whether any scientific findings are published related to these flights. If no reports appear in the literature, they will probably remain to be counted as minor military.

Kosmos 752 is also unclear as to purpose. It was placed in an orbit of 65.9 degrees, just like the target craft of the 1971–72 period, an inclination not previously used for any other flights by the C–1 vehicle. It may be a "minor military" flight like Kosmos 660 at 83 degrees inclination and Kosmos 687 at 74 degrees inclination, but this flight is more nearly in circular orbit than 660 and 687. Aside from the inclination, Kosmos 752 is a close match in apogee and perigee for Kosmos 461 which flew at 69 degrees, and which in time was revealed as scientific.

9. Non-Military Uses of the C–1 Launch Vehicle

Table 6–4 is added here in the interest of completeness and comparability to account for the other uses of the C–1. These were discussed in an earlier chapter and need no further discussion now.

TABLE 6-3.—PROBABLE MILITARY SPACE FLIGHTS USING THE C-1 LAUNCH VEHICLE BY KOSMOS NUMBER, APOGEE AND PERIGEE

Year	Tyuratam												Plesetsk—74° single low		
	56° multiple eccentric			56° multiple low circular			56° multiple highest circular			56° single low					
	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee
1964	38–40	876	210												
1965	53–55	1, 192	227	71–75	550	550	80–84	1, 500	1, 500	103	600	600			
	61–63	1, 837	273				86–90	1, 690	1, 380						
1967										151	630	630	189	600	535
1968										236	655	600	200	536	536
													250	556	523
1969													269	558	526
													315	556	521
1970													330	548	514
													358	549	517
													387	560	528
1971													395	570	534
													425	556	511
													436	550	514
													437	558	523
													460	553	520
1972													479	549	517
													500	554	509
													536	555	514
1973													544	561	513
													549	556	513
													582	559	521
													610	560	515
1974													631	565	522
													655	549	520
													661	555	513
													698	566	515
1975													707	550	505
													749	557	511
													781	557	508

Footnotes at end of table.

Year	Plesetsk														
	74° single lower middle			74° single upper middle			74° single high			74° single higher			74° multiple highest		
	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee
1964															
1965															
1967	192	760	760	158	850	850									
1968	220	760	670							203	1,200	1,200			
										256	1,234	1,168			
1969	292	786	747							272	1,220	1,195			
	304	774	747							312	1,187	1,145			
1970	332	786	775	372	828	786	385	1,005	982				336–343		
	371	780	754											1,500	1,400
1971				407	844	799	422	1,020	994	409	1,222	1,185	411–418		
				468	830	788	465	1,023	984	457	1,229	1,912		1,530	1,408
													445–451		
														1,550	1,415
1972				494	829	791	475	1,013	977				504 511		
				540	823	779	489	1,010	988	539	1,353	1,302		1,540	1,425
													528–535	1,495	1,375
1973				614	830	770				585	1,416	1,385	564–571	1,507	1,392
													588–595	1,512	1,397
													617–624	1,511	1,404
1974				676	840	799				650	1,413	1,380	641–648	1,508	1,385
										675	1,429	1,370			
													677–684	1,519	1,451
1975				773	828	791									
													711–718	1,530	1,449
				783	838	797									
													732–739	1,532	1,475
													761–768	1,537	1,454

Footnotes at end of table.

TABLE 6-3.—PROBABLE MILITARY SPACE FLIGHTS USING THE C-1 LAUNCH VEHICLE BY KOSMOS NUMBER, APOGEE AND PERIGEE—Continued

Year	Plesetsk														
	83° single high			83° single higher			69.2° single higher			65.9° single targets			Miscellaneous		
	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee
1964															
1965															
1967															
1968															
1969															
1970															
1971										394	619	574			
										400	1,016	995			
										459	277	226			
1972	514	999	959	480	1,212	1,183				521	1,030	973			
1973	574	1,026	996												
	586	1,020	986												
	627	1,032	991												
1974	628	1,026	975										660	(83°)	
	663	1,017	983											1,995	409
	689	1,032	992										687	(74°)	
	*700	1,012	976											717	292
1975	*726	1,008	972	770	1,222	1,188	708	1,493	1,387	752	526	480			
	729	1,023	995												
	*755	1,025	991												
	*778	1,018	989												

NOTES

*Forming a second pattern, offset from the previous pattern by 20°, noted by the Kettering Group.

1. This table includes all C-1 launched flights which have not been given explanations in the scientific literature or the press and are presumed to be fulfilling military missions until proven otherwise.

2. The flights are grouped by years, by launch site, by approximate inclination, and by general category of apogee and perigee.

3. Apogee and perigee are given in kilometers.

4. Kosmos 256, though military, carried a solar and cosmic ray experiment.

5. Kosmos 610, though military, carried a nonrecoverable biological experiment.

SOURCES: All data on the flights are from Soviet TASS bulletins as summarized in Appendix A, plus data from the Kettering Group.

TABLE 6-4.—OTHER SPACE FLIGHTS USING THE C-1 LAUNCH VEHICLE BY KOSMOS NUMBER OR NAME, APOGEE AND PERIGEE

Year	Kapustin Yar—50.7° circular			Plesetsk											
				69° circular			74° eccentric			74° circular			83° eccentric		
	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee
1970							378	1,756	241	381	1,023	985			
1971				461	524	490	426	2,012	394						
							Oreol 1	2,500	410						
1973	546	630	585				IK-10	1,477	265						
							Oreol 2	1,995	407						
1974	IK-11	526	484				IK-12	708	264						
1975	Ariabat	619	563				IK-14	1,707	345				IK-13	1,714	296

NOTES

1. This table includes all C-1 launched flights which have been explained in the scientific literature or in the Soviet press.
2. The flights are grouped by years, by launch site, by approximate inclination, and by general category of apogee and perigee.
3. Flights include not only Kosmos, but Interkosmos (indicated by the prefix IK), and those given the names Oreol (Aureole) and Ariabat (Aryabhata).
4. Apogee and perigee are given in kilometers.
5. It is possible at some future date that scientific missions will be disclosed for Kosmos 752 which has the external characteristics of a science payload; also, this could be true of Kosmos 660 and 687, although the latter are more likely to be "minor military" missions.

SOURCES: All data on the flights are from Soviet TASS bulletins as summarized in Appendix A of this study.

C. USE OF THE F–1–M LAUNCH VEHICLES AT TYURATAM

The newest of the Soviet space launch vehicles to come into use has been that derived from the SS–9 Scarp very large ICBM. In at least one of its versions, it may be carrying an upper stage which was paraded in Moscow as the final stage of the SS–10 Scrag which itself never entered the operational missile inventory. But the SS–10 appellation as "global" used in parade descriptions ultimately was transferred to the SS–9 and this may have been brought about by salvaging for further use this final stage. The F series of launch vehicles is unique in that not one has been applied to any civilian program. There have not even been accounts of supplemental scientific payloads. Further, this larger vehicle, capable of carrying up to 4,500 kilograms of payload, and unlike the awkwardly shaped A class vehicles with their cryogenics, uses storable propellants, and can be placed in a silo launch facility.

With its size and general flexibility, the vehicle has been used for several quite different kinds of missions, indicated by the marked differences in flight mode among each of the groups and even with these groups. Also, with inertial guidance almost certainly a feature, these vehicles have shown some versatility in being launched at a greater variety of azimuths from a given launch facility. All the space launches with the F vehicles have come from Tyuratam.

Table 6–5 which follows summarizes all the F class flights.

1. Weapons Use of the F–1–r Launch Vehicle

Chapter One has already discussed the major known events related to the development and use of the F class vehicles. In this context, our interest is in defining the missions of these flights for military purposes. In greater detail than already summarized in the earlier chapter, the weapons use of the F–1–r came to be recognized through the following sequence of events. Table 6–6 gives greater details on these flights.

TABLE 6-5.—PROBABLE MILITARY SPACE FLIGHTS USING THE F-1-r OR F-1-m LAUNCH VEHICLE BY KOSMOS NUMBER IF ANY, APOGEE AND PERIGEE

	Tyuratam																	
	50° eccentric			50° low orbit			62–64° intermediate			62–66° eccentric			65° low and high			65° intermediate		
Year	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee
1966:																		
Sep 17¶		1,046	163															
Nov 2¶		855	140															
1967				139	210	144	185	888	522				198	281	265*			
				160	205	142												
				169	208	144												
				170	208	145												
				171	220	145												
				178	205	145												
				179	208	145												
				183	212	145												
				187	210	145												
1968				218	210	144	217	520	396#	249	2,177	514	209	282	250*			
				244	212	140	248	551	490	252	2,172	538						
1969	316	1,650	154	298	212	140	291	574	153									
1970				354	208	144	373	553	490	374	2,153	536	367	1,030	932§			
				365	210	144				375	2,164	538						
1971				433	259	159				397	2,317	593	402	279	261*			
										404	1,009	811	469	276	259*			
										462	1,840	237						
1972													516	277	256*			
1973													626	280	257*			
1974													651	276	256*	699	454	436
													654	277	261*			
1975													723	277	256*	777	456	437
													724	276	258*			
													785	278	259*			

NOTES

*Later moved to higher orbit.
#Announced, not attained.
§Started in lower orbit, not announced.
¶Date of unannounced flight.

1. This lists all known uses of the F class family of launch vehicles for orbital flight purposes.
2. Flights are grouped according to their orbital characteristics of inclination, apogee and perigee.
3. Apogee and perigee are listed in kilometers.
4. The 1966 flights have never been acknowledged or named by the Russians.
5. Kosmos 217 was announced as having attained an intermediate altitude orbit, but was never detected there by Western sensors; instead short-lived debris was found in lower orbit.
6. The column marked "low and high" were all payloads which started their flights in low orbit, and during the course of the flight separated into several parts, with one segment moved to high orbit. All but Kosmos 367 were announced as launched, in low orbit; the exception also started in low orbit, but only the high parameters were announced after the separation and maneuver.
7. Later tables treat various categories of F class flights in greater detail.

SOURCES: All data are from Soviet TASS bulletins, as summarized in Appendix A of this study. The two unannounced flights were carried by the Royal Aircraft Establishment (RAE) and the Goddard reports on satellites, which sources also located the debris of Kosmos 217 and the maneuvers of the "low and high" group.

TABLE 6-6—APPARENT WEAPONS RELATED FLIGHTS OF THE F-1-r LAUNCH VEHICLE

Name	Launch date	COSPAR desig.	Object	Length and diameter (meters)	Weight (kg)	Lifetime	Eccentric orbit				FOBS			
							Apogee	Perigee	Incli-nation	Period	Apogee	Perigee	Incli-nation	Period
None	Sep. 17, 1966	88A	Payload	6 x 1.5		54	1,046	163	49.6	96.1				
		88B	Rocket	8 x 2.5	1,500	168	1,010	280	49.3	97.6				
		88C	Object			23	523	214	49.8	91.9				
		88E	Object			279	1,275	289	50.3	100.6				
		88?	Rocket				245	193						
None	Nov. 2, 1966	101A	Payload	6 x 1.5		15	855	140	49.6	94.5				
		101B	Rocket	8 x 2.5	1,500	20	507	134	49.4	91.5				
		101C	Object			13	1,513	123	49.2	101.3				
		101G	Capsule	0.8 x 0.8	1,000	185	830	144	49.6	94.3				
Kosmos 139	Jan. 25, 1967	5A	Payload	2 x 1.0		0.06					210	144	50.0	87.5
		5B	Rocket	8 x 2.5	1,500	0					210	144	50.0	87.5
		5C	Platform			0					210	144	50.0	87.5
Kosmos 160	May 17, 1967	47?	Payload	2 x 1.0		0.06					205	142	49.6	87.8
		47A	Rocket	8 x 2.5	1,500	0.8					177	137	49.7	87.6
		47B	Platform			0.8					177	137	49.7	87.6
Kosmos 169	July 17, 1967	69A	Payload	2 x 1.0		0.06					208	144	50.0	87.6
		69B	Platform			1					129	128	49.6	87.0
		69C	Rocket	8 x 2.5	1,500	0.3					103	102	49.6	86.5
Kosmos 170	July 31, 1967	74A	Payload	2 x 1.0		0.06					208	145	50.0	87.9
		74B	Rocket	8 x 2.5	1,500	0.3					263	126	49.4	88.3
		74C	Platform								191	123	49.4	87.6
Kosmos 171	Aug. 8, 1967	77A	Payload	2 x 1.0		0.06					220	145	50.0	87.6
		77B	Platform			0.6					200	130	49.6	87.7
		77D	Rocket	8 x 2.5	1,500	0.3					165	134	49.6	87.4
		77E	Object								318	137	49.5	89.0
Kosmos 178	Sep. 19, 1967	89A	Payload	2 x 1.0		0.06					205	145	50.0	87.8
		89B	Platform			0.5					209	130	49.7	87.9
		89C	Rocket	8 x 2.5	1,500	0.2					163	137	49.6	87.4
Kosmos 179	Sep. 22, 1967	91A	Payload	2 x 1.0		0.06					208	145	50.0	87.9
		91B	Platform			0.4					212	120	49.5	87.7
		91C	Rocket	8 x 2.5	1,500	0.2					156	141	49.4	87.4
Kosmos 183	Oct. 18, 1967	99A	Payload	2 x 1.0		0.06					212	145	50.0	87.9
		99B	Platform			0.5					179	127	49.7	87.5
		99C	Rocket	8 x 2.5	1,500	0.3					211	151	49.3	88.1
Kosmos 187	Oct. 28, 1967	106A	Payload	2 x 1.0		0.07					210	145	50.0	87.8
		106B	Platform			0.4					298	139	49.6	88.8
		106C	Rocket	8 x 2.5	1,500	0.3					240	139	49.6	88.2

Name	Launch date	COSPAR desig.	Object	Length and diameter (meters)	Weight (kg)	Lifetime	Eccentric orbit: Apogee	Eccentric orbit: Perigee	Eccentric orbit: Incli-nation	Eccentric orbit: Period	FOBS: Apogee	FOBS: Perigee	FOBS: Incli-nation	FOBS: Period
Kosmos 218	Apr. 25, 1968	37A	Payload	2 x 1.0		0.07					210	144	50.0	87.8
		37B	Rocket	8 x 2.5	1,500	0.2					167	131	49.6	87.4
		37C	Platform			0.5					172	133	49.6	87.5
Kosmos 244	Oct. 2, 1968	82A	Payload	2 x 1.0		0.06					212	140	50.0	87.3
		82B	Rocket	8 x 2.5	1,500	0.3					159	133	49.6	87.3
		82C	Platform			0.5					193	149	49.6	87.8
Kosmos 298	Sep. 15, 1969	77A	Payload	2 x 1.0		0.06					212	140	50.0	87.3
		77B	Rocket	8 x 2.5	1,500	0.3					156	123	49.6	87.2
		77C	Platform			0.5					169	134	49.6	87.5
Kosmos 316	Dec. 23, 1969	108A	Payload	4 x 1.5	5,000?	249	1,650	154	49.5	102.7				
		108B	Platform			8	920	130	49.5	95.1				
		108C	Rocket	8 x 2.5	1,500	36	1,581	147	49.5	102.2				
Kosmos 354	July 28, 1970	56A	Payload	2 x 1.0		0.06					208	144	50.0	87.3
		56B	Rocket	8 x 2.5	1,500	0.4					157	114	49.6	87.1
		56C	Platform			0.5					178	134	49.6	87.5
Kosmos 365	Sep. 25, 1970	76A	Payload	2 x 1.0		0.06					210	144	49.5	87.5
		76B	Platform			0.4					174	133	49.7	87.5
		76C	Rocket	8 x 2.5	1,500	0.3					161	117	49.7	87.2
Kosmos 433	Aug. 8, 1971	68A	Payload	2 x 1.0		0.06					259	159	49.5	88.5
		68B	Platform			1.8					300	112	49.5	88.6
		68C	Rocket	8 x 2.5	1,500	1.0					104	142	49.5	87.6

NOTES

1. All uses of the F–1–r launch vehicle at inclinations close to 50 degrees from Tyuratam are included
2. Flights are subdivided between those in fairly eccentric orbits, and those known to be fractional orbit bombardment satellites (FOBS) in low orbit.
3. The orbital elements of the payloads are as announced by the Russians; all other orbital elements are from Western sources (they are in kilometers), as are all estimates on identifications of objects, dimensions, and weights, as well as life times to retrofire or natural decay.
4. Some of the numbers even though contained in official reports are suspect because of various internal inconsistencies.
5. The RAE data on dimensions and weights are not confirmed. C. P. Vick prefers 8.9×3 meters for the rocket dimensions, rather than the RAE's 8×2.5 meters.

SOURCES: Soviet identifications of payloads by name and original orbital elements are from TASS bulletins as summarized in Appendix A of this report. All the rest of the data are from the reports of the Royal Aircraft Establishment, except for an occasional extra piece of debris of particular interest, where the data have been drawn from the Goddard Satellite Situation report.

Reference has already been made to Soviet analyses of U.S. military space plans carried in *Red Star* and other Soviet newspapers. When Col. Glazov wrote his attack on U.S. purported misuse of space, he divided these activities into (1) those of military support and control, and (2) military destruction of objects on Earth or in space. He claimed that the reason the U.S. Department of Defense would not publish statistics after early 1962 on the Discoverer satellites was that these were practicing the techniques of calling down warheads from orbit when they retrofired their capsules to Earth. He claimed U.S. development of orbital bombs was well along. He said U.S. ability to use satellites for intercepting and destroying other satellites was understood in principle and would be sought, but was much farther away from being operational. In America's relatively open society we have a perspective which permits us to distinguish between unofficial proposals for such systems and the hard realities of no authorizations and no funds for pursuing this type of work. The United States today has neither orbital bombardment systems nor space-based interceptor systems. But there has often been the suspicion in the Western world that when the Soviet authorities approve the printing of charges against other nations we may be experiencing symptoms of their own psychological defense mechanisms at work attempting to put the blame on others for what they themselves either are considering or are already doing on a covert basis. There have been enough examples over the years to make this not an unreasonable suspicion even if not true in every instance. In any case, Col. Glazov supplied some interesting descriptions of coming technologies.[21]

The military parade through Red Square in May 1965 included a new, very large three-stage liquid fueled ICBM, the SS–10 Scrag. The Soviet radio announcer said:

> Three-stage intercontinental missiles are passing by. Their design is improved. They are very reliable in use. Their servicing is fully automated. The parade of awesome battle might is being crowned by the gigantic orbital missiles. They are akin to the carrier rockets which confidently put into space our remarkable spaceships like Voskhod 2. For these missiles there is no limit to range. The main property of missiles of this class is their ability to hit enemy objectives literally from any direction, which makes them virtually invulnerable to anti-missile defense means.[22]

The corresponding parade in November that same year included the same Scrag missiles, and the description given was:

> Now in front of the rostrum giant missiles are passing. These are orbital rockets. Warheads of orbital rockets are able to inflict sudden blows upon an aggressor on the first or any other orbit around the Earth.[23]

These parades of orbital rockets brought negative reactions in foreign circles, particularly because the Soviet Union was a leading participant in the draft treaty banning weapons of mass destruction from outer space. *Izvestiya* replied editorially, noting that a U.S. Department of Defense spokesman had said that the U.N. Resolution banning weapons from orbit did not preclude production of such rockets.

> McCloskey was forced to agree with these pronouncements. How could he do otherwise when the world knows that the United States has long used outer space for espionage purposes and its aggressive military ends. Further, it is clear to

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[21] Glazov, V. Cosmic weapons, Red Star, Moscow, January 26/27, 1965.
[22] Moscow Radio, May 9, 1965.
[23] Moscow Radio, November 7, 1965.

everyone that intercontinental missiles are also space weapons. They are fired via outer space, and the United States, as frequently stated by the Pentagon brass, is constantly increasing their output.[24]

In December 1965, the Soviet Union announced test flights of a "variant of a space vehicle landing system, with some elements of the carrier rockets falling" at the specified Pacific Ocean danger zone. There was no claim that a payload would be recovered at this location.[25] This showed that a multistage vehicle of some complexity was being used. With most systems, the lower stages usually fall in the Soviet Union, with a final stage and payload perhaps going beyond. By contrast, this time, a discarded stage was falling in the Pacific, and the payload, which was suborbital must have been called down by retrofire into Soviet territory. In light of developments which came in the next two years, we can surmise that the F class vehicle was being applied to the early stages of testing what was to become the Fractional Orbital Bombardment System—FOBS.

In May 1966 the Moscow parade still contained the Scrag missiles and they were still described as orbital, but were given very brief mention.[26] The same was true in the November 1966 parade.[27] That same month, Lt. Gen. Pavel B. Dankevich made passing reference to the fact that silo launchers could be used for both intercontinental and orbital missiles, and these missiles could carry warheads ranging from several dozen to 100 megatons of nuclear explosive force.[28]

On September 17 and again on November 2, 1966, the Russians made space launchings which were the first since January 1963 to be totally unacknowledged. One can only speculate whether these were launches which failed their ultimate purpose to the extent of being ignored, like the Venus, Mars, and Moon flights of 1962–63, or whether they were not regarded as anything other than related to the military global rocket program and therefore somehow not necessary to acknowledge. These flights came out of Tyuratam on a new inclination—49.6 degrees, suggesting use of a new rocket or new launch pad or both. Debris or staging were left at several altitudes. It was even possible that more than one stage had been deliberately blown up in orbit to protect this hardware from chance compromise should it later decay nearly intact in some place it might be recovered.

These two events threw confusion into U.S. information policies again as similar secret Soviet launches had in 1962. On the earlier occasion, the Goddard Satellite Situation Report was forced to suspend publication for many months while officials wrangled over whether it would endanger security or strain relations if the United States listed such Soviet launches. That time, the giveaway even to library readers was that the sequential COSPAR numbers assigned all objects in orbit were being skipped. This time, those making the decisions apparently thought the thing to do was to ignore the Soviet launches by not assigning them COSPAR numbers as well as omitting them from the Goddard report. But this did not work either. Objects were in orbit and astronomers and radar operators were finding them, and it made it look as if the United States either was playing games or

[24] Quoted by TASS, November 10, 1965, 1651 GMT.
[25] TASS, December 14, 1965, 1848 GMT.
[26] Radio Moscow, May 2, 1966.
[27] Radio Moscow, November 7, 1966, 0736 GMT.
[28] Radio Moscow, November 18, 1966, 1430 GMT.

suddenly had lost its ability to track. So eventually, the secret Soviet flights were given COSPAR numbers, the only flights whose numbers were out of chronological sequence. This showed the difficulty of trying to make decisions by fiat when obvious physical facts cannot be made to conform to a directive for something to "disappear". It was clearly awkward for the United States in all of its processes of orderly record keeping and impartial openness in what probbaly should have been a non-sensitive area. Perhaps within the Soviet Union there were similar struggles among scientists, engineers, public relations (propaganda), and security people. All we know is for the nine years since that time, the Russians have announced all space flights without regard to their program or how they performed.

Because of the amount of debris and conflicting information on sizes of pieces related to these particular flights, one can make only arbitrary judgments as to what elements to list in a table. The launch of September 17 apparently had clusters of debris from a second stage in low circular orbit, more debris from a third stage in eccentric orbit, and a payload somewhat higher. More than 100 pieces were detected. Apogees ranged from about 250 kilometers to about 1,300 kilometers.

The similar flight of November 2 also left debris in perhaps 50 pieces and at apogees ranging from 500 kilometers to about 1,500 kilometers, again suggesting that the Russians must have triggered separate explosions in each abandoned stage and in the payload after at least some of these had performed their different though related functions.

A third flight of the same kind came in 1969, but was announced as Kosmos 316. This time there was no evidence of wholesale explosions. Some kind of stage or platform was left with an apogee of 920 kilometers, while a final rocket stage had an apogee of 1,581 kilometers, and the payload reached 1,650 kilometers.

All three of these flights had low enough perigees that orbital stay time was relatively brief from a few weeks to a few months. When Kosmos 316 decayed, it broke up into a number of parts, which is not uncommon, and these parts largely rained down across the American Midwest, providing some spectacular fireworks. Presumably most fragments burned in the atmosphere, but some chunks did reach the surface and were recovered. These were in Oklahoma, Kansas, and Texas. Some were said to measure up to a meter and more in maximum dimension, and weighed up to tens of kilograms. In accordance with international agreements, these pieces after preliminary study were shipped to Washington to be returned to the Soviet Union, which refused to accept them as theirs. A possible consideration for their reluctance was related to concern over potential damage claims. What was interesting is the rumor that some of the pieces more nearly resembled parts of a bomb casing than a normal rocket structure. This latter report is heresay evidence and not documentable from published records.

Most analysts seem to have classified these three flights as FOBS flights which in some fashion malfunctioned, and then were exploded. This analysis does not seem to stand up because the placement of the stages and debris are not that closely akin to the FOBS flights patterns which are much lower. Also, some pieces of these flights pro-

duced telemetry for varying amounts of time beyond what would be expected if there had been early explosions which made the whole flights errant.

What one can say is that the three mystery flights went at an inclination which has been flown only by FOBS, and using a vehicle exclusively tied to military programs. Under these circumstances, the flights seems to be weapons-related. The question which has come up in some minds, was whether they related to an orbital bomb program, since the Russians had indicated it was possible to call down weapons either during the first orbit or to leave them up longer. That question cannot be answered to complete satisfaction. A potential weapon which was to have a long stay-time in orbit would presumably be given a higher perigee, closer to circular. But if the flight were developmental, and there was a desire to insure that exploded remnants of any test vehicle would be down in a few months, then the patterns chosen might make sense. Near-Earth space would be less cluttered for many years to come, and any whole parts not exploded would not be in orbit long enough to be inspected in some future year when such capabilities finally became available. Also, a weapon (in follow-on to these experiments) put up in a crisis lasting for only a few weeks would perhaps find acceptable deployment with the kind of eccentric orbits selected.

One is left with unresolved questions about these three flights.

In 1967, there were new developments in the use of the F class vehicles. As flights occurred, they were promptly announced and given Kosmos names and numbers. All flew at 49.5 to 50 degrees from Tyuratam. All were distinctive in that the orbital elements as announced included the inclination, apogee and perigee, but not the orbital period. Since all had pieces which stayed in orbit for a number of hours or even over a day, it was clear that the Russians regarded these pieces of debris in lingering orbit as something different from the significant payload portion, whose stay time was less than one orbital period. Typical was the TASS bulletin on the first of these flights:

> A routine launching of the artificial satellite Kosmos 139 took place in the U.S.S.R. Scientific apparatus intended for the continuation of research into outer space is installed on board.
>
> The satellite has been put into an orbit with the following parameters: maximum distance from the surface of the Earth—apogee—210 kilometers; minimum distance from the surface of the Earth—perigee—144 kilometers; inclination of orbit 50 degrees.[29]

The insertion of the word "routine", not normally used, almost arouses one's curiosity as to what was up; and of course, this has been one of the most controversial programs for space undertaken by any nation. The open literature very quickly reflected the special nature of these flights, that the payload was being retrofired just short of one orbit, leaving staging and debris to decay naturally in the hours and orbits to follow. Some writers immediately speculated that there was a weapons implication. Others were sure what they were seeing were reentry tests in follow-up to the death of Komarov in Soyuz 1. It is interesting how strongly this view was held, considering the facts weighing against this. The first flight came before the death of Koma-

[29] TASS, January 25, 1967, 1708 GMT.

rov. The orbit flown was different from that used for any manned flight, when tests would normally be close analogs of what men would do later if the tests were to provide valid data and experience. During 1967 alone there were nine of these flights. The public explanation came on the afternoon of November 3, 1967 from the U.S. Secretary of Defense, who tagged them as probable FOBS flights. He pointed out that such test flights did not of themselves violate the space treaty and resolutions banning weapons of mass destruction from orbit, both because they flew less than one orbit, and because in all likelihood they did not carry nuclear warheads while undergoing development. He pointed out that the launch vehicle when used as a FOBS would carry a smaller warhead than when the same vehicle was used as an ordinary ICBM, and also that a FOBS might be less accurate in finding its target. He did note that the flights heightened U.S. interest in developing a precautionary interception capability, and also escalated the arms race. He noted that if a FOBS came by the most direct route over the north polar regions that it would fly with a lower apogee than regular ICBM's and hence would give a shorter warning time to the BMEWS defense radars. If it came the long way around over the southern approaches, there was less detection equipment to note its approach. If a warhead were to be fired from what otherwise seemed to be a routine satellite flight, it would take about six minutes for it to move from previous orbit to impact its target on the surface of the Earth.

It was interesting that every one of the FOBS flights from 1967 until 1971 when they were terminated on that initial fractional orbit did not once cross the continental territory of the United States. The regular path at that inclination carried them mostly eastward and very slightly north from Tyuratam across Siberia, down through the central Pacific, across the lower part of South America, up the Atlantic, and across Africa and the Mediterranean to impact after retrofire on Soviet territory not far from the launch site. Some miscellaneous debris stayed up enough orbits that with the rotation of the Earth, the debris crossed over the United States.

After the nine flights of 1967, apparently the testing phase was complete, for only one or two flights a year continued in the next four years. In connection with the SALT talks, or perhaps coincidentally, all flights ceased in 1971, not to resume in the next four years since then.

In 1967, at the end of that busy year of intensive testing, and just days after the American Secretary of Defense had drawn public attention to FOBS, there came the long awaited fiftieth anniversary Moscow parade. As in the several previous parades, the Scrag missile was displayed, but it was no longer described as an orbital rocket:

> They were followed by three-stage intercontinental rockets firing [sic] new, highly efficient kinds of propellant. They need little time to be readied for firing and can be launched from silos and other launching ramps.[30]

The account went on to describe the following rockets which were being unveiled for the first time. These were the SS–9 Scarp. TASS reported:

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[30] TASS, November 7, 1967, 0710 GMT.

The last to appear were mammoth rockets each of which can deliver to target nuclear warheads of tremendous power. Not a single army in the world has such warheads. These rockets can be used for intercontinental and orbital launchings.[31]

Radio Moscow elaborated a little bit on the same occasion:

And here they are showing a new type of rocket . . . with a new type of fuel, one of the new high efficiency fuels that they are now using. I can see everyone intently watching this display. And now they are showing what are perhaps the most powerful strategic rockets; they have blunt noses; they can carry the most powerful nuclear warheads and deliver them to any point on Earth. These are ballistic rockets; they can also be used for orbital flights—a very heavy type of rocket.[32]

Department of Defense testimony before Congress has indicated that the SS–10 Scrag did not enter the operational inventory; indeed it may not even have flown. But the SS–9 Scarp of course has become well known as the heaviest Soviet missile until very recently, now exceeded by the new SS–18. The Department of Defense also identified the SS–9 as providing the basic stages for the FOBS flights. We do not know why the SS–10 did not become the orbital rocket it was supposed to, but there is always the possibility that the final stage of the SS–10 survived to become the orbital stage on the SS–9, giving us the F-l-r rocket which was tested from 1965 to 1971.

What is the meaning of no flight activity since 1971? It could mean that the Russians decided that FOBS flights are not cost effective, as did the United States. It could mean that they are fully operational and sitting in their silos intermixed with regular SS–9's. It could even be that behind the scenes, missile commanders chafe at the restrictions on troop training, normally afforded by practice flights, and at limits on product improvements through evolution, all in the interest of a political decision not to risk detente and future arms agreements.

The American Secretary of Defense pointed out some of the limitations of a FOBS system. Military planners have pointed out that the right pattern of bombs in orbit, fractional or otherwise, would not have to be large in number to destroy most of the available Strategic Air Command (SAC) bases, and certainly to raise hob with many other aspects of U.S. second strike capabilities. Such a sudden call-down would take six minutes, as the Secretary of Defense reported. But the number of FOBS or similar flights required to take out SAC aircraft would not also take out all the U.S. missiles in silos and in submarines at sea. There would almost certainly be unacceptable losses to the Soviet Union of military power, industrial capacity, and human lives from the U.S. second strike after such a FOBS or related attack. A similar equation would apply in reverse if the United States had a FOBS, which now it both lacks and does not plan to acquire.

Every additional weapon system which another powerful nation acquires complicates the defense of other nations. While FOBS was not technically a violation of the treaty against orbiting weapons of mass destruction, it was not calculated to ease tensions between the two super powers.

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[31] Idem.
[32] Radio Moscow, November 7, 1967, 0755 GMT.

2. Military Interceptions for Inspection and Destruction

Although the F class vehicles had come into weapons-related use possibly as early as 1965 and certainly by 1966, these have all been classed as using the F–l-r type of vehicle with its retro-package which at least in the case of FOBS was used to bring back a dummy warhead before natural decay would occur.

On October 27, 1967, a new type of vehicle appeared, the F–l-m, marked by use of a maneuvering stage with a multiple burn capability. As further flights of this launch vehicle occurred, there was a considerable variety of uses or patterns, as sometimes the whole assembly seemed to maneuver as a unit, and sometimes there were abandoned rocket stages and launch platforms before the final payload ended up in still another orbit. In some cases maneuvers occurred so promptly the original orbit was not readily detected by the regular Western sensors; other times, there was a lapse of time. All of this makes it difficult to be absolutely sure how many operational modes have been observed, and how many times the apparent differences were occasioned more by getting data readings at different times during the flights. The first major grouping of F–1–m flights is summarized in Table 6–7.

Kosmos 185, the first of the F–1–m flights, was put into a slightly eccentric low orbit, and then both the payload and the accompanying carrier rocket maneuvered upward to a somewhat higher, still eccentric orbit, which was the one announced prosaically by the Russians. No purpose was given for the flight.

Kosmos 217, launched April 24, 1968, was announced as being in an orbit similar to the initial orbital pattern of Kosmos 185. But Western sensors found only debris in a low orbit, similar to that of a FOBS flight. There was a suspicion that the payload may not have achieved sustained orbit at all. Presumably the announced orbit was the one intended as the initial orbit, even though not attained. It raised questions as to why a patently not achieved orbit was made public.

TABLE 6-7—THE SOVIET MILITARY SPACE INTERCEPTOR PROGRAM, WITH ORBITAL CHANGES

Name	Launch date	Probable targets				Interceptors				
		Apogee	Perigee	Inclination	Period	Apogee	Perigee	Inclination	Period	Disposal
Kosmos 185	Oct. 27, 1967	546	370	64.1	93.6					
Do		888*	522*	64.1*	98.7*					
Kosmos 217	Apr. 24, 1968	262	144	62.2	88.5					
Do		520*	396*	62.2*	93.4*					
Kosmos 248	Oct. 19, 1968	~260	~140	~62.3	~88.5					
Do		551*	490*	62.3*	94.8*					
Kosmos 249	Oct. 20, 1968					254	136	62.3	94.8	
Do						2,177*	514*	62.4*	112.2*	E
Kosmos 252	Nov. 1, 1968					~250	~140	~62.0	~94.8	
Do						2,172*	538*	61.9*	112.5*	E
Kosmos 291	Aug. 6, 1969	574*	153*	62.3*	91.5*					
Kosmos 373	Oct. 20, 1970	1,102	510	62.8	100.9					
Do		553*	490*	62.9*	94.8*					
Kosmos 374	Oct. 23, 1970					1,053	530	62.9	100.6	
Do						2,153*	536*	63.0*	112.3*	E
Kosmos 375	Oct. 30, 1970					~1,000	~500	~62.8	~100.0	
Do						2,164*	538*	63.0*	112.4*	E
Kosmos 394 C	Feb. 9, 1971	619*	574*	65.9*	96.5*					
Kosmos 397	Feb. 25, 1971					~613	~144	~65.1	~92.1	
Do						2,317*	593*	65.8*	114.7*	E
Kosmos 400 C	Mar. 19, 1971	1,016*	995*	65.8*	105.0*					
Kosmos 404	Apr. 4, 1971					~632	~148	~65.1	~92.3	
Do						1,009*	811*	65.9*	103.0*	
Do						799	169	65.2	94.0	R
Kosmos 459 C	Nov. 29, 1971	277*	226*	65.8*	89.4*					
Kosmos 462	Dec. 3, 1971					~1,561	~143	~62.3	~102.0	
Do						1,840*	237*	65.8*	105.7*	E
Kosmos 521 C	Sept. 29, 1972	1,030*	973*	65.8*	105.0*					
Kosmos 752 C	July 24, 1975	526*	480*	65.9*	94.6*					

NOTES

1. This table includes all F-1-m targets and interceptors, plus all C-1 vehicles which flew at the right inclination to be targets.
2. The apogee and perigee are in kilometers, the inclination in degrees, and the period in minutes.
3. Those marked with an E were deliberately exploded after fulfilling their missions of interception. That marked with an R was instead commanded to reenter over deep ocean where its remnants would sink beyond recovery.
4. Where targets are listed without follow-on interceptors, the mission is only inferrable, not certain. Kosmos 521 may have been a target that was not matched by an interceptor. Kosmos 752 was much more likely not to have been a target.
5. The flights marked with a C were conducted with use of the C-1 type of launch vehicle instead of F-1-m like all the others.
6. The Soviet-announced orbital elements are marked with asterisks; all other orbital elements were preliminary and later elements measured by Western sensors.

SOURCES: The list of vehicles and their principal orbital elements are from Soviet TASS bulletins as summarized in Appendix A of this study. The other supplementary orbital elements are from the Royal Aircraft Establishment.

On October 19, 1968, Kosmos 248 was put into an orbit like that announced for but not attained by Kosmos 217. It may have started in a lower initial orbit, but that is not clear.

A day later, Kosmos 249 was launched, probably leaving a rocket casing in a low orbit reminiscent of FOBS which decayed the next day. Then Kosmos 249 was maneuvered into a markedly eccentric orbit whose perigee was very close to the average attitude of the Kosmos 248 orbit. It was adjusted to come into close proximity to Kosmos 248. The initial Soviet bulletin on this flight added new phraseology: "Scientific investigations under the program have been carried out." Indeed, what happened was that after the satellite had made its high speed close inspection of Kosmos 248, it moved away again, and was exploded into a cloud of debris.

On November 1, Kosmos 252 was put into orbit in a pattern virtually identical to that of Kosmos 249. Again, it made a high speed flyby of Kosmos 248, moved away, and was exploded into many fragments. The initial Soviet announcement said: "The scientific research envisioned by the program has been fulfilled." Because the orbits of Kosmos 249 and 252 were so placed that they would have lasted many years, the prompt announcement of program completion was a pretty good indication that the explosions coming as they did in a pair were planned.

This made evident that the Russians who had practiced cooperative rendezvous and docking with Kosmos 186 and 188 and again with Kosmos 212 and 213, were now conducting inspections of what could be non-cooperative craft. The explosions of these two payloads could mean that they carried instrumentation and other devices the Russians did not want to leave in orbit for some future generation of curious inspectors of another nationality to find; or they could have been exercising the destruct mechanism, presumably at a safe distance so as not to destroy their own target.

Now it was possible to go back and put into context other statements and attitudes. It was interesting that during the period the Russians were criticizing the United States for having an MOL (Manned Orbiting Laboratory) plan, they credited MOL with a capability of inspecting and destroying the satellites of other nations. This was carried in *Red Star* in 1965, and was one of the more preposterous things credited to that unwieldy, long tank with its human crew at one end, and its limited propulsion capability.[33]

The Russians were aware that at one point the United States had under early development an unmanned system called Saint which was supposed to co-orbit with potentially dangerous foreign satellites to inspect them. This program, as well as MOL, was abandoned by the United States. Apparently, by contrast, the Russians went ahead with their parallel system, and added a destruction capability to the inspection phase.

With the experience of Kosmos 248, 249, and 252, it was possible to go back through earlier flights and to discover that Kosmos 217 and 185 had enough characteristics in common that they were either precursor engineering tests or were parts of systems, presumably targets, which failed before any interceptors could be sent up.

[33] Viktorev, G, The olive branch and space arrows, Red Star, Moscow, September 21, 1965.

In this same time period, there was an East German reference to such a capability:

Under combat conditions it would undoubtedly be possible to stop the extensive radio communications required for navigational purposes; moreover, it would not be too difficult to put the satellites out of operation with the help of weapons systems which, for example, the Soviet Army has at its disposal. And thus the entire system would, of course, be ineffective.[34]

The Russians themselves made an oblique reference to destruction of satellites in October 1969. An attack was made on plans for a NATO communications satellite. The charge was made that the real purpose of the satellite was espionage rather than communications:

Why does NATO have to extend its space program? The crux of the matter is that whereas before aircraft and ships were considered fairly satisfactory vehicles for collecting intelligence information about the socialist countries in Europe and Asia, they are no longer satisfactory . . . Everyone is aware of how a U–2 reconnaissance plane was shot down over Soviet territory. This year a new intelligence aircraft, the EC–S–121 was shot down over North Korea. All this forced NATO to change its tactics. . . . The new NATO tactical satellite program suggests that the United States is dragging its NATO pact allies into its strategy of total espionage and is successfully ferreting considerable funds out of them to cover the cost of constructing espionage centers in various countries. The rejoinder of the armed forces of the Warsaw Pact member countries is to undertake reliable measures to protect themselves from the aggressive activities and aspirations of the NATO pact.[35]

On August 6, 1969, Kosmos 291 had been put into low eccentric orbit, where it separated a carrier rocket. There was no further maneuver, and it may have been a target for further interceptor tests which were cancelled, when it failed to raise its perigee to match Kosmos 248, or to go still higher like the vehicles of the following year.

On October 20, 1970, Kosmos 373 may have started in low orbit, but was first detected in a stable orbit with a fairly high apogee and moderately low perigee. Very shortly the apogee was lowered to circularize the orbit at virtually the same level as Kosmos 248 of two years earlier. It left its carrier rocket in a more extreme orbit, with about the high perigee of the payload before its downward maneuver, and its perigee much lower than any measured perigee of the payload.

Three days later, Kosmos 374 was launched into the same kind of initial orbit as Kosmos 373. Then it maneuvered again to raise its apogee twice as high, but leaving its perigee at the average orbital altitude of the final orbit of Kosmos 373. It was in this final orbit that it separated from its carrier rocket. It made a close pass by Kosmos 373, moved away, and was exploded into many pieces of debris. The now familiar language of the initial Soviet press bulletin included the news that the envisaged program had been completed.

On October 30, Kosmos 375 was launched in a virtual repeat of the steps followed by Kosmos 374. The initial orbit was the eccentric one like the initial orbits of both Kosmos 373 and 374. The next major maneuver greatly raised apogee, and here the carrier rocket was separated. It made its near pass by Kosmos 373, moved away and was exploded. The TASS bulletin initially released also announced the experiment planned had been completed.

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[34] Otto. Major Manfred, National Zeitung, East Berlin, September 14, 1968, p. 6.
[35] Radio Moscow, October 13, 1969, 2030 GMT.

There is not too much doubt that the two sets of triplet flights, each involving a double intercept were all of a pattern, but there are many unanswered questions about staging and procedures, as the visible record has inconsistencies which are not readily resolved.

In the absence of any Soviet discussion of the flights or findings from "experiments", there has been speculation in the West about the operating modes and purposes of the Soviet interceptor tests. A few people saw them as purely benign for space rescue purposes. It seems unlikely that the Russians would go to such expense to develop a humanitarian system without open discussion of it, to take some credit for their generosity. Other people were convinced that the F–1–m target vehicle was the destroyer craft, reasoning that since the interceptors, not the target were being destroyed, this would be a proper interpretation. Supposedly if the U.S. Saint project had been seen through to completion, and it conducted a passive inspection in co-orbit with a sensitive Soviet military payload, then the ability to destroy the Saint could be a possible Soviet countermove against such inspection. Since most estimates are that the explosions in the inspectors took place at some considerable distance from the targets, it seems more likely that the explosions were generated in the F–1–m inspectors, whether to preserve the secrecy of their possibly advanced technology hardware, or in exercise of an ability to shower a simulated target with shrapnel through self-destruction, after a real interception and inspection had been conducted. In real combat, if the interceptor-gathered data suggested the target was a threat, ground controllers could send a command to the interceptor to explode while within range of the target.

It would be interesting to know why a vehicle as large as the F–1–m was used to launch the targets, unless nothing smaller at that time could be placed in the same orbital plane as the interceptors. In any case, a new feature was introduced into the program in the flights of 1971.

On February 9, 1971, Kosmos 394 was launched from Plesetsk using a C–1 vehicle in a brand-new inclination—65.9 degrees. It was put into a circular orbit about 600 kilometers above the Earth, where it was separated from its carrier rocket.

On February 25, Kosmos 397 was launched from Tyuratam using the F–1–m again, also on a new inclination for this vehicle—65.8 degrees. It started out in low orbit, where it dropped its carrier rocket. It then moved to an eccentric orbit very much like those of Kosmos 249, 252, 374, and 375. It made an inspection of the target, moved away, and was exploded.

Kosmos 400 was launched by a C–1 at Plesetsk on March 19, 1971, but this time was placed in a circular orbit about 1,000 kilometers up, where it separated from its carrier rocket.

On April 4, 1971, Kosmos 404 was launched at Tyuratam with the F–1–m vehicle. It left its carrier rocket in an intermediate eccentric orbit, then climbed to a near-circular orbit ranging from about 1,000

to about 800 kilometers, where it made quite a different pass by its target. Where other interceptions had been made with a considerable differential in velocity, this was more of a lingering inspection. There was another change. After the inspection, the interceptor was not exploded. This time the perigee was lowered sharply so that the orbit ranged from 799 kilometers to 169 kilometers, and a controlled deboost brought it to decay over an ocean area with deep water where it could not be recovered. This had the advantage of not cluttering near Earth space with scores or even hundreds of shards of metal.

On November 29, 1971, Kosmos 459 was launched at Plesetsk using the C–1, and it was put into the lowest orbit ever flown by that launch vehicle—about 250 kilometers, roughly circular. It separated from its carrier rocket.

Kosmos 462 was launched on December 3, 1971 at Tyuratam, using the F–1–m. Its carrier rocket was abandoned in a highly eccentric orbit, even more extreme than those of Kosmos 397 and 404. With minor adjustments, the payload after separation maintained essentially that same eccentric orbit, and at its perigee swept by Kosmos 459 for a high speed inspection, before moving on and then exploding.

As in every one of the seven successful interceptions, the Soviet initial bulletin also announced the completion of the test with the attainment of its intended objectives, never stated.

On September 29, 1972, Kosmos 521 was also launched from Plesetsk using the C–1 vehicle, and it flew at the inclination of 65.9° used by all the Plesetsk target craft and by no other C–1 craft. There was no follow-up interception. Was such a flight planned but cancelled? We do not know. This same inclination finally came into use again in 1975 when Kosmos 752 was launched on July 24, 1975. Like the FOBS flights, the interceptor flights ended in 1971, perhaps in connection with the SALT talks although these items were not formally negotiated as activities to be dropped. As indicated, the Kosmos 521 flight almost a year later may or may not have been an incomplete continuation of this program, a target without a seeker. Kosmos 752 after almost three more years looks even less like a target despite its inclination, although this remains to be resolved.

Some people have noted that the three known interceptions of C–1 class targets afforded the Russians an opportunity to demonstrate they could make interceptions at altitudes often put to use by electronic ferret payloads, weather satellites, navigation satellites, and military recoverable observation satellites. Many people were sure that we would see similar tests against targets at 36,000 kilometers altitude, but it seems unlikely any such have been carried out, and it is also unlikely the same interceptor payloads could be carried that high by an F–1–m launch vehicle, so that instead the D–1–e civilian launch vehicle would have to be adapted to military use, to achieve a similar inspection at so high an altitude.

TABLE 6-8.—MILITARY OCEAN SURVEILLANCE FLIGHTS OF F-1-m

Date of launch, Name	Dimensions length and diameter	Apogee	Perigee	Inclination	Period	Remarks
Dec. 27, 1967:						
Kosmos 198	14 x 2	281	265	65.1	89.8	Separated and raised
Do	6 x 2	952	894	65.2	103.4	payload Dec. 29, 1967
Rocket	6 x 2	273	241	65.1	89.6	after 2 days.
Platform	2 x 2	246	223	65.1	89.0	
Mar. 22, 1968:						
Kosmos 209	14 x 2	282	2 50	65.1	89.6	Separated and raised
Do	6 x 2	944	871	65.3	103.1	payload Mar. 28, 1968
Rocket	6 x 2	236	210	65.1	89.0	after 6 days.
Plaform	2 x 2	267	227	65.1	89.5	
Oct. 3, 1970;						
Kosmos 367	14 x 2	[280]	[250]	[65.2]	[89.6]	Separated and raised
Do	6 x 2	1,030	932	65.3	104.5	payload Oct. 3, 1970
Rocket	6 x 2	246	226	65.2	89.2	the day of launch.
Platform	2 x 2	264	246	65.1	89.6	
Apr. 1, 1971:						
Kosmos 402	14 x 2	279	261	65	89.7	Separated and raised
Do	6 x 2	1,036	948	65.0	104.9	payload Apr. 9, 1971
Rocket	6 x 2	258	239	65.0	89.5	after 8 days.
Platform	2 x 2	263	247	65.0	89.6	
Dec. 25, 1971:						
Kosmos 469	14 x 2	276	259	65	89.7	Separated and raised
Do	6 x 2	1,023	941	64.5	104.7	payload Jan. 4, 1972
Rocket	6 x 2	255	244	65.0	89.5	after 10 days.
Platform	2 x 2	261	247	65.0	89.6	
Aug. 21, 1972:						
Kosmos 516	14 x 2	277	256	65	89.6	Separated and raised
Do	6 x 2	1,030	920	64.8	104.6	payload Sep. 21, 1972
Rocket	6 x 2	255	239	65.0	89.4	after 31 days.
Platform	2 x 2	259	243	65.0	89.5	
Dec. 29, 1973:						
Kosmos 626	14 x 2	280	257	65	89.7	Separated and raised
Do	6 x 2	990	910	64.9	104.0	payload Feb. 11, 1974
Rocket	6 x 2	296	234	65.0	89.8	after 44 days.
Platform	2 x 2	257	237	65.0	89.4	
May 15, 1974:						
Kosmos 651	14 x 2	276	256	65	89.6	Separated and raised
Do	6 x 2	954	892	65.0	103.5	payload July 25, 1974
Rocket	6 x 2	258	243	65.0	89.5	after 71 days.
Platform	2 x 2	262	245	65.0	89.6	
May 17, 1974:						
Kosmos 654	14 x 2	277	261	65	89.7	Separated and raised
Do	6 x 2	1,024	913	65.0	104.4	payload July 30, 1975
Rocket	6 x 2	261	248	65.0	89.6	after 74 days.
Platform	2 x 2	381	192	65.1	90.2	
Apr. 2, 1975:						
Kosmos 723	14 x 2	277	256	65	89.6	Separated and raised
Do	6 x 2	951	916	65	103.7	payload May 15, 1975
Rocket	6 x 2	258	249	65	89.6	after 43 days.
Platform	2 x 2	234	220	65	89.0	
Apr. 7, 1975:						
Kosmos 724	14 x 2	276	258	65	89.7	Separated and raised
Do	6 x 2	938	868	65.5	103.0	payload June 11,
Rocket	6 x 2	253	240	64.9	89.4	1975 after 65 days.
Platform	2 x 2	257	246	65.0	89.6	
Dec. 12, 1975:						
Kosmos 785	14 x 2	278	259	65	89.7	Separated and raised
Do	6 x 2	1,023	898	65.1	104.3	payload Dec. 13, 1975
Rocket	6 x 2	260	248	5.0	89.6	after 0.68 days.
Platform	2 x 2	260	248	65.0	89.6	

NOTES

1. This table includes all F-1-m flights with the characteristics of the ocean surveillance program.
2. The Kosmos number, date of launch, and initial orbital elements are as announced by the Russians, except for Kosmos 367 which lacked such initial announcement; instead their post-maneuver announcement has been listed.
3. The fact of later separation into three major parts and the new orbits for these three parts (the main payload with nuclear power source to high orbit at the close of the mission) and the formerly integral rocket unit and platform left in low orbit) are all from British data, except for Kosmos 367, after maneuver.
4. Apogee and perigee are in kilometers; inclination is in degrees, and period is in minutes.
5. C. P. Vick believes the Royal Aircraft Establishment (RAE) dimensions listed in the table understate the reality. He gives the rocket stage as 8.9 x 3 meters, instead of 6 x 2 meters. If he is correct, other dimensions should be increased also.

SOURCES: Basic Kosmos numbers, dates and orbits from Soviet TASS bulletins. All subsequent data are from the Royal Aircraft Establishment (RAE).

3. Military Ocean Surveillance Using Radar

Back in 1967, shortly after Kosmos 185 introduced use of the F–1–m launch vehicle, the same launch vehicle was used to begin a different

series from those intended as targets or interceptors. What was unique and special about this different series is that every flight started out in an orbit around 270 kilometers circular, and then later produced several objects, one of which climbed to about 950 kilometers circular, while the other two main objects shortly decayed from their unchanged low orbit. Table 6–8 summarizing these flights.

The first of these flights was Kosmos 198, which moved to higher orbit, a part of its original single assemblage without separated carrier rocket, after two days. Kosmos 209 the following year made its similar split and partial move after six days. In 1970, Kosmos 367 moved so promptly to its higher orbit, leaving behind the other pieces in the low orbit that the Russians announced only the final, higher orbit. Two such flights came in 1971, moving up part of the payload after 8 and 10 days respectively. The 1972 test made its move after 31 days. The 1973 test moved up after 44 days, while the 1974 tests moved up after 71 and 74 days respectively, and the first 1975 tests moved up after 43 and 65 days respectively.

Such anomalous behavior raised considerable comment in the Western trade press, without any good theories being offered for many years. Finally some clues were offered by the U.S. Navy which said the Soviet Union had been developing an ocean surveillance system whose flights had begun in the 1960's.[36]

Then things began to fall into place. The same week independently, the American press carried a story, and G. E. Perry of the Kettering Group in the United Kingdom came up with the same interpretations. Their analysis, whether self derived (Perry) and possibly inspired (by DoD sources?), suggested a coherent picture of what was going on. This was that the Russians were testing a surveillance satellite designed to seek out naval movements at sea anywhere in the world, regardless of weather and regardless of ships maintaining radio silence. To do this, they would presumably correlate any data from general intelligence on ship movements, including direct port observations, comint, and long range sonar with radar data from satellites. In order to get a good enough radar signal, they needed to keep the radar carrying satellite in fairly low orbit, and on successive passes would sweep large areas of ocean with a signal strength great enough to provide some analyzable return signal. Further, to generate the power levels required, they probably were using a nuclear power source with a fairly short half life for an RTG (radioactive thermal generator), rather than the more modest amounts of power which solar panels would provide. The argument further ran, if a radioactive source with a short half life were used, it might carry risks of atmospheric and surface pollution when the payload decayed soon from low orbit. Hence, the operating mode was to make the radar survey in low orbit, and when it was indicated through telemetry that the sensors and processing equipment was about to fail, explosive bolts were blown to separate the original rocket and as much of the hardware as possible to permit natural decay. But the dangerous part of the payload with the radioactive RTG equipment was fired by an integral rocket to carry the "payload" to a higher altitude where a typical decay time was 600

[36] Director Naval Intelligence, Understanding Soviet Naval Development, Washington: U.S. Navy, 1974.

years. This would provide such a margin of safety that many half-lives later, the ultimate decay of the nuclear material would provide a minimal hazard to the Earth.

If one can accept the British measurements, the complete payload was about 14 meters long, while after the split, about 6 meters moved to the high orbit, and two pieces, 6 meters and 2 meters respectively remained behind. These have been labeled the rocket and the platform by the Royal Aircraft Establishment (REA), which may be correct, or may be an unwarranted identification. C. P. Vick estimates the rocket portion as 8.9 by 3 meters; if he is correct, the other figures probably should be increased also.

The clue to the analysis now carried widely in the press and trade journals is the lengthening time between attainment of initial orbit and the later split and partial elevation. For several years it was assumed that the higher orbit was important to conduct of the mission, and no one could understand why there was the delay in moving up. The tie of need for radar, the use of a nuclear power source, and the final need to dispose of the radioactivity finally made possible the link of the U.S. Navy testimony and reports with this big, previously unexplained series of Soviet flights.

4. Remainder of the F–1–m Program

The above sections account in some fashion for all the F class flights but two. The first of these was Kosmos 699, launched on December 24, 1974 into a 65 degree inclination orbit just like the ocean surveillance flights. But this time the orbit was circularized at a little over 400 kilometers high, leaving a carrier rocket in a lower eccentric orbit. At first it looked like an evolutionary step in the ocean surveillance program. This was not borne out when the next pair of ocean surveillance flights appeared in April 1975 at the same altitudes as the rest of the ocean series. Kosmos 699 on April 18, 1975, was apparently deliberately exploded into many fragments rather than being broken into three parts and then one part shifted to higher orbit.

Hence the mission of Kosmos 699 cannot be assigned to any previous family, and typically it takes a number of flights of a given type before one can begin to deduce missions, unless the Russians themselves explain. As this is almost certainly a military program, there was no further press release after the first basic announcement of orbital parameters. Geoffrey Perry and Russell Attwood at Kettering Grammar School studied changes in the mean orbital period of Kosmos 699 and concluded that the spacecraft's mission involved trials of a micro-thruster which, over a period of months moved the payload both up and down as if electric rocket tests were being carried out.[37]

Perry, with two more of his pupils, John Kellett and Stuart Ganney, observed similar changes in the mean orbital periods of Kosmos 723 and Kosmos 724, prior to their maneuvers into higher orbits at the close of their active phase of ocean surveillance, which suggested that such a microthruster was being used on each for station-keeping. Perry and Ganney noticed that the micro-thruster onboard Kosmos 723 went into a continual active mode on about April 7, thereby de-

[37] Perry, G. E., and R. J. Attwood, Flight International, London, May 1, 1975, p. 718.

stroying the relative spacing between the two satellites. At launch, Kosmos 724 was some 27 minutes behind Kosmos 723 with an orbital plane separation of 23 degrees. On the day before Kosmos 723 was moved into the higher orbit the difference had decreased to less than two minutes. Perry suggests that this was the cause of the relatively shorter active phase of Kosmos 723 (only 43 days compared with 71, 74, and 65 days for Kosmos 651, 654, and 724 respectively). Similar maneuvers had been associated with Kosmos 382, the D–1–e lunar-related, man-related test payload. Since Kosmos 382 at least had no other point in common with these F–1–m payloads, so far as one can judge, it seems likely that the electric rocket tests in all cases were only supplemental or auxiliary to the main purposes of all of these flights. No other military payload had flown at the altitude of Kosmos 699, although the closest fits have been the F–1–m targets of the 1967–1971 period and the continuing series of C–1 elint ferrets of many years. The C–1's and the F–1–m targets have neither been blown up after completing their missions, so there was something, probably, that was considered more sensitive about this flight unless it was only happenstance that it was destroyed. Kosmos 777, launched on October 29, 1975 with elements of 456 by 437 kilometers, 65 degrees, and 93.3 minutes, looked like a very close repeat of Kosmos 699. It remains to be seen whether it will supply additional clues to permit the assignment of a reasonable mission to this pair of flights. Sven Grahn in Sweden has found that Kosmos 777 was transmitting on 166 MHz, a frequency also used by the ocean surveillance types. Perry noted that this flight also used a probable ion-thruster system to adjust the orbit over a period of time.

The final 1975 test, Kosmos 785, was very similar to those of the ocean surveillance pairs, but it was moved into the higher orbit, leaving two pieces in the lower orbit, after only ten revolutions. This immediately caused speculation about premature failure, but Perry's analysis of mean orbital period suggests that small orbital corrections are made from time to time implying the payload is not dead.[38] Grahn monitored likely frequencies and discovered that it was transmitting on 180 MHz instead of 166 MHz, typically used by the pairs of ocean surveillance flights.[39]

D. MILITARY USE OF THE A–1 LAUNCH VEHICLE

In 1964, an A–1 launch vehicle was used at Tyuratam to put up an unexplained payload in a circular orbit at about 700 kilometers. This was Kosmos 44. As similar flights came over a five year period, first at that launch site, and later at Plesetsk, the use was finally revealed as support of a weather reporting system by returning cloud cover television pictures.

In 1969, the same kind of weather satellites were put into orbit with some differences in altitude, but mostly around 650 kilometers circular, and they were now given the name Meteor. In 1970 and 1971 each year there was one flight at about 890 kilometers circular, and since that time, it has become the standard for continuing operational weather satellites.

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[38] Perry, G. E., Private communication, January 18, 1976.
[39] Grahn, S., Private communication, January 25, 1976.

In 1970, in virtually the same kind of orbit at the first series of Meteor payloads, there came Kosmos 389. The most likely supposition was that this was a weather satellite which had failed, and hence had been given a Kosmos name instead of a Meteor name, so as to hide the fact that no weather pictures were being returned.

This supposition almost certainly was wrong. Each year for six years a single repeat of this kind of flight has occurred. The Meteor failure explanation no longer fits. Furthermore, all the Meteors since the beginning of 1972 have flown at the new, higher altitude while these Kosmos flights continue at the older, lower altitude.

With no published findings, these flights almost have to be military in nature. Next, one applies the kind of analysis which permitted the sorting out of each of the different families of C–1 military flights to look for possible matches which might suggest that a later generation craft was coming into use which might carry more equipment than a smaller C–1. Where the C–1 payloads which put up singly may range about 800 kilograms, an A–1 would probably put up three to four times that much (2,400 to 3,200 kilograms).

There are not enough of these payloads to provide a navigation system, and no such telemetry has been discovered coming from these flights. They are not high enough to be helpful for geodetic work. They could handle store dump communications on a limited basis. But they come closest in altitude to the C–1 electronic ferret flights. Hence, most Western observers have counted these flights as belonging in the latter category. Undoubtedly having a larger A–1 satellite than the payload used in the major C–1 elint system already described would afford extra opportunities to monitor a wider range of electromagnetic frequencies, record more data for later replay, and carry on board more special equipment for preliminary analysis of signals detected. There also might be some division of labor between two classes of elint satellites. The big network in planes 45 degrees apart might be used mostly for capturing a large volume of communications where messages are heard only once. The more complex and less common larger elint satellites might concentrate on specialized sources of electromagnetic signals such as radars where presumably the class of signals would be repetitive. There seems no way to determine the accuracy of such speculations based upon material in the public domain.

Table 6–9 lists all the A–1, non-recoverable uses for military purposes, and for convenience includes parallel columns for weather satellites, so the general relationships of flight mode can be compared.

TABLE 6-9.—USE OF THE A-1 LAUNCH VEHICLE INCLUDING PROBABLE MILITARY NONRECOVERABLE SPACE FLIGHTS AS WELL AS OTHERS BY KOSMOS NUMBER OR OTHER NAME (EXCLUDING ELEKTRON), APOGEE AND PERIGEE

Year	Tyuratam 65°			Plesetsk 81°														
	Early Kosmos			Early Kosmos			Meteor 1 low			Meteor 1 high			Meteor 2			Later Kosmos		
	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee
1964	44	860	618															
1965	58	659	581															
	100	650	650															
1966	118	640	640															
	122	625	625															
1967				144	625	625												
				156	630	630												
				184	635	635												
1968				206	630	630												
				226	650	603												
1969							1	713	644									
							2	690	630									
1970							3	643	555	5	906	863				389	699	655
							4	736	637									
							6	674	633									
1971							7	679	630	10	905	880				405	706	676
							8	646	620									
							9	650	618									
1972										11	903	878				476	651	618
										12	929	897						
										13	904	893						
1973										14	903	882				604	647	624
										15	909	867						
1974										16	906	853				673	648	620
										17	907	877						
										18	905	877						
										19	917	855						
										20	910	861						
1975										21	906	877	1	903	872	744	650	612
										22	918	867				756	649	627

NOTES

1. This table includes all known uses of the A-1 launch vehicle for non-recoverable missions, except for the Elektron flights whose flights were quite different from the rest of the table.

2. Flights are grouped by launch site, inclination, and name, giving apogee and perigee in each case.

3. Apogee and perigee are in kilometers.

SOURCES: All data are from Soviet TASS bulletins as summarized in Appendix A of this report.

E. MILITARY USES OF THE A–2–E LAUNCH VEHICLE

In 1964, Kosmos 41 was put into a 12-hour, semi-synchronous orbit, which would repeat its ground trace each day. This orbit carried it from a low point around 400 kilometers in the southern hemisphere and reaching to 65 degrees south latitude, to a high point almost 40,000 kilometers high in the northern hemisphere and reaching to 65 degrees north latitude. One climb each day came over North America, while the other came over Eurasia.

A year later, the purpose of the test became apparent when the Molniya 1 satellites came into operation to support the Orbita system of domestic communications already described in another chapter. Eventually, most of the Molniya launches came from Plesetsk, and then Molniya 1 came to be paralleled by a Molniya 2 and even a Molniya 3. Their several functions have already been described.

Also in 1964, Elektron 1 and 2 were put up as a pair in January, with the first payload ranging out to about 7,000 kilometers, and the second out to about 68,000 kilometers. Elektron 3 and 4 were put up as a similar pair, six months later, and 12 hours different as to hour of launch. The Elektron flights have had many scientific findings published about them, and in function they were roughly equivalent to the American POGO flights to gather geophysical data. Western analysts noted that their announced weights and their big spreads of solar cells provided more experiment capacity than had been announced. This raised the possibility that these satellites had a secondary mission of providing engineering data required for building a missile and nuclear explosion detection system for the Russians. This added use cannot be confirmed. The Elektron series despite their eccentric orbits used the A–1 class of launch vehicle.

In 1967, Kosmos 159 was put up at Tyuratam using the A–2–e like the Molniya flights, but ranging out to 60,600 kilometers and at an inclination of about 52 degrees. It most certainly looked as if it would be a scientific successor to the Elektron flights, but strangely no findings have filled the literature as one would expect. So, either the payload failed, or it also was planned as a military development flight, also looking like an early warning test for missile detection, or a nuclear detection flight to guard against any surprise tests of nuclear devices in the atmosphere or in space. However, a recent unpublished hypothesis by David R. Woods suggests Kosmos 159 was related to the manned program and his case is convincing. It is discussed in another chapter.

In 1967 and again in 1968, there were individual flights which looked very much like Molniya flights, from Tyuratam. These were called Kosmos 174 and Kosmos 260. They seemed as if they could be Molniya 1 failures, or were military communications satellites. Now that increasingly, the Molniya 1 flights look as if they were dedicated to military use, there would seem to be little reason not to use the Molniya name for these two Kosmos flights, if they were merely military communications satellites.

With the passage of time, one is led rather strongly toward a parallel to the situation of military Kosmos flights which match the Meteor flights. If so, then Kosmos 174 and 260 were not Molniya flights, but some new, military mission. This view is strengthened by the fact that more recently each year a single flight with a Kosmos name in the Molniya pattern is launched from Plesetsk. While all the current Molniya 1, 2 and 3 family launchings are conducted at an inclination of 62.8 to 63 degrees, every one of them has an apogee over 40,000 kilometers, almost an average of 40,800 kilometers. But each of the four Kosmos flights at this inclination has an apogee of 39,000 kilometers approximately, most typically 39,400 as a average value. This seems fairly convincing that they are not Molniya failures. Even more convincing, the Kosmos flights have not been in the right planes to fit the patterns described by Perry and Perkins.

One can only speculate as to the mission if it is not communications. The United States has given some prominence in testimony before Congress to its early warning satellites which are placed in 24-hour synchronous orbits to give warning of all space and missile launchings, with information on trajectory and type signatures, particularly in infrared. This is the same kind of orbit that the United States uses for most of its current communications satellites. Because the Russians have the same need for early warning to supplement their home ground-based radars, it seems only natural with their most frequent use of inclined, eccentric orbits for communications, that they would transfer this proven technique to their early warning needs as well. The 12-hour orbit with its two high lobes in the northern hemisphere would be very good in supplying wide coverage in those regions where missile operations would be most likely. On one daily pass, all of North America would be in view, plus coverage of the arctic; on the other pass, all of Eurasia would be in view plus coverage of the arctic.

Again, this is a mission that cannot be confirmed from public sources of information, but the mission need is so obvious and the usefulness of the satellites is such a good fit that this analysis is reasonably satisfying as a working hypothesis until proven otherwise.

A parenthetical footnote can be added: The D–1–e vehicle is not known to have been dedicated to military uses, except for the military manned space station, but perhaps with the upgrading of capacity common in other missions, it must be recognized that the next time a few years hence a review of this nature is prepared, the picture will be changed. It may be concluded that the Molniya 1–S in 24-hour synchronous orbit is the first of military satellites in fixed positions in parallel to military Molniya 1 satellites in 12-hour orbits. Likewise, Kosmos 775 also in 24-hour synchronous position may be an engineering test for Statsionar "civilian" communications satellites, or it might be the first of a series of military early warning satellites put up in parallel to Statsionar, in the same way there are parallels between Molniya comsats and these similar Kosmos early warning orbits.

Table 6–10 summarizes the A–2–e Earth orbital missions, plus the Elektron A–1 missions, to compare and contrast these several uses.

TABLE 6-10.—USE OF THE A-2-e LAUNCH VEHICLE FOR ECCENTRIC EARTH ORBIT SPACE FLIGHTS INCLUDING PROBABLE MILITARY KOSMOS BY NUMBER AND OTHERS BY NAME WITH APOGEE AND PERIGEE (PLUS ELEKTRON A-1 FLIGHTS)

Year	Tyuratam														
	Elektron (A-1) 61°			Kosmos 52°			Prognoz 65°			Molniya 1 65°			Kosmos 65°		
	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee
													41	39,855	394
1964	1	7,100	406												
	2	68,200	460												
	3	7,040	405												
	4	66,235	459							1	39,957	548			
1965										2	40,000	500			
										3	39,500	499			
1966										4	39,700	485			
										5	39,810	460	174	39,750	500
1967				159	60,600	380				6	39,600	465			
										7	39,740	456			
										8	39,700	460	260	39,600	500
1968										9	39,770	470			
										10	39,600	490			
										11	39,700	470			
1969										12	39,540	520			
										17	39,600	480			
1970															
1971							1	200,000	950	22	39,100	500			
1972							2	200,000	550						
							3	200,000	590	23	39,200	470			
1973										25	39,140	480			
1974															
1975							4	199,000	644						

	Plesetsk																	
	Kosmos 63°			Molniya 1 63°			Molniya 2 63°			Molniya 3 63°			Molniya 1 66°			Molniya 2 66°		
Year	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee	Number	Apogee	Perigee
1964																		
1965																		
1966																		
1967																		
1968																		
1969																		
1970													13	39, 175	487			
													14	39, 280	470			
													15	39, 300	480			
													16	39, 430	430			
1971													18	39, 300	470	1	39, 350	460
													19	39, 200	490			
1972	520	39, 319	622										20	39, 260	480	2	39, 300	460
													21	39, 300	480	3	39, 200	480
1973	606	39, 360	626	26	40, 900	460	7	40, 600	630				24	37, 970	480	4	39, 300	470
																5	39, 100	500
																6	39, 280	480
1974	665	39, 384	633	27	40, 713	646	8	40, 865	466	1	40, 690	650						
				28	40, 617	683	9	40, 850	463									
							10	40, 900	460									
							11	40, 675	641									
1975	706	39, 812	635	29	40, 848	468	12	40, 685	640	2	40, 660	636						
				30	40, 890	450	13	40, 864	465	3	40, 930	470						
				31	40, 681	639	14	40, 836	470	4	40, 800	470						
							15	40, 836	451									

NOTES

1. This tables includes all uses of the A class of launch vehicle for eccentric Earth orbits. Most of these were put up using the A-2-e, although the A-1 was used for the Elektron flights.

2. The table arranges these flights by year, by name, by launch site and by inclination, and shows the apogee and perigee of each.

3. Apogee and perigee are in kilometers.

SOURCES: Data are from Soviet TASS bulletins as summarized in Appendix A of this study.

F. USE OF THE A–1 AND A–2 LAUNCH VEHICLES FOR MILITARY RECOVERABLE OBSERVATION MISSIONS

In effect, this section is the culmination of any analysis of Soviet military uses of space. Previous sections of the report have "disposed" of the myriad of other uses by all classes of Soviet launch vehicles. Had the Russians not stopped flying in 1971 their FOBS and their interceptors, these might have become the central, dominant part of the program, with degrees of escalation of rivalry which are almost better not contemplated. The many other uses have important contributions in toto. But the commitment of resources to large payloads of which the A–2 in particular is able to put up, and the fact that there are more of these flights each year than in any other category makes them very important.

Analysis of these flights has taken much time, which is commensurate with their importance. The world leader in such work, as far as the public domain is concerned, is Geoffrey E. Perry whose name has come up in many other contexts in this study. Because his original international reputation was built on his ability to understand the variations in these Kosmos flights, he has been invited to make some direct contributions to this study, and two of these are offered as annexes to this chapter (as well as an additional study as an annex to a different chapter). The Kettering work grew out of observations of the Doppler shift of frequencies received from Soviet satellites as an instructional aid to the teaching of physics. The continuing work over lunch hours provided unconscious training in the "scientific method" to successive generations of pupils, some of whom are named in the annexes to this chapter for their specific contributions.

Table 6–11 summarizes Soviet military observation recoverable flights whose prime purpose is believed to be photographic reconnaissance, although other military data gathering and a variety of supplemental payloads may also be carried. Not unexpectedly for a large and high priority program, the Russians have lavished considerable attention on improving both hardware and flight operations. The Russians have barely acknowledged the program even exists, and then only obliquely; hence, it is not easy to understand everything about its character and subtleties. This table gives a comprehensive overview by sorting out the individual flights by years, by major hardware generations, by possible camera resolutions, and by telemetry patterns and recovery beacons, with further indications about supplemental payloads or experiments where known or suspected. The table also shows the duration of each flight until it was recalled to Soviet territory for recovery, or showing it was exploded if recovery seemed doubtful. The flights are listed by launch site and by general inclination. A rather long list of notes accompanies the table to point out special features and points in dispute about classifications.

Then follows Table 6–12 which summarizes the same information on a single page showing totals by year and by group characteristics, to make it easier to comprehend the trends than does the preceding more detailed complete listing. Finally, in the group, is Table 6–13, which takes the same flights and counts by years the number flown at each inclination announced by the Russians, since the first of the tables in inclination grouping was less precise. This precision reveals that choice of the A–1 and A–2 launch vehicles (shown in the table separately) often matches the particular inclinations reported by the

Russians, and hence is another way of identifying some launch vehicles beyond the usual method of making observations visually and by radar of the final stage in orbit.

TABLE 6-11.—SOVIET MILITARY PHOTOGRAPHIC RECOVERABLE KOSMOS MISSIONS BY KOSMOS NUMBER AND DAYS DURATION

Year and category	Launch Site and Inclination: Tyuratam 51–52°	Tyuratam 65°	Tyuratam 69–71°	Plesetsk 62–63°	Plesetsk 65–66°	Plesetsk 67°	Plesetsk 72–73°	Plesetsk 81°
1962								
1st Generation Low Resolution		4BW (3)						
		7BW (4)						
		9W (4)						
		10 (4)						
		12 (8)						
1963								
1st Generation Low Resolution		13 (8)						
		15W (5)						
		16 (10)						
		18 (9)						
		20 (8)						
		24 (9)						
2nd Generation High Resolution		22 (6)						
1964								
1st Generation Low Resolution	32 (8)	28 (8)						
	35 (8)	29 (8)						
	46 (8)	33 (8)						
	50 [*]	37 (8)						
		48 (6)						
2nd Generation High Resolution		30 (8)						
		34 (8)						
		45W (5)						
1965								
1st Generation Low Resolution		52 (8)	78 (8)					
		64 (8)						
		66 (8)						
		68 (8)						
		98 (8)						
		99 (8)						
2nd Generation High Resolution	67 (8)	59 (8)						
	77 (8)	65 (8)						
		69W (8)						
		79 (8)						
		85 (8)						
		91 (8)						
		92BW (8)						
		94B (8)						
1966								
1st Generation Low Resolution		104 (8)			129 (7)		112 (8)	
		105 (8)			136S (8)			
		107 (8)						
		115 (8)						
		117 (8)						
		132 (8)						
2nd Generation High Resolution	126 (9)	109B (8)					114 (8)	
	127 (8)	113 (8)					121 (8)	
		128 (8)					131 (8)	
		130 (8)						
		134S (8)						
2nd Generation Low Resolution	120 (8)							
	124 (8)							
1967								
1st Generation Low Resolution	157 (8)	143S (8)			138 (8)			
					147 (8)			
					153 (8)			
2nd Generation High Resolution	155 (8)	182 (8)			150 (8)		141 (8)	
	172 (8)				161 (8)		175 (8)	
					190 (8)			
					194 (8)			
2nd Generation Low Resolution	162 (8)				164 (6)		180 (8)	
	168 (8)				181 (8)			
	177 (8)				193 (8)			
					195 (8)			

TABLE 6–11.—SOVIET MILITARY PHOTOGRAPHIC RECOVERABLE KOSMOS MISSIONS BY KOSMOS NUMBER AND DAYS DURATION—Continued

Year and category	Launch Site and Inclination							
	Tyuratam			Plesetsk				
	51–52°	65°	69–71°	62–63°	65–66°	67°	72–73°	81°
1968								
2nd Generation	224S (8)	201 (8)			207 (8)		229 (8)	214 (8)
High Resolution	227 (8)				232W (8)			
	234 (6)				237 (8)			
	239 (8)				241 (8)			
					246 (5)			
					254 (8)			
2nd Generation	216 (8)	231 (8)			199 [*]		223 (8)	210 (8)
Low Resolution	235 (8)	258 (8)			205 (8)			
	240 (7)				247 (8)			
					253 (8)			
					255 (8)			
3rd Generation	228 (12)	208 (12)	243 (11)					
Low Resolution								
PDM-Science								
3rd Generation		251 (12)						
High Resolution								
Morse-Maneuverable Science								
1969								
2nd Generation	279 (8)	267 (8)			270 (8)		297 (8)	276 (7)
High Resolution	284S (8)	274S (8)			271 (8)			
	288 (8)	296 (8)			282 (8)			
		299 (4)			286 (8)			
		310 (8)			289 (5)			
					294 (8)			
					302 (8)			
2nd Generation	287 (8)				263 (8)		266 (8)	
Low Resolution					273 (8)			
					278 (8)			
					281 (8)			
					290 (8)			
					301 (8)			
3rd Generation	293 (12)				309 (8)			
Low Resolution								
PDM-Science								
3rd Generation		306 (12)			313 (12)			
Low Resolution								
PDM								
3rd Generation	280 (13)		264 (13)					
High Resolution								
Morse-Maneuverable-Science								
3rd Generation					317 (13)			
High Resolution								
2-tone Maneuverable								
1970								
2nd Generation	345 (8)	331 (8)			322 (8)			
High Resolution	346 (7)				323 (8)			
	352 (8)				349 (8)			
					355 (8)			
2nd Generation					325 (8)		344 (8)	326 (8)
Low Resolution								
3rd Generation		368 (6)					384 (12)	
Low Resolution								
PDM-Science								
3rd Generation	350 (12)	318 (12)			353 (12)			329 (12)
Low Resolution		363 (12)						
PDM		366 (12)						
		377 (12)						
3rd Generation		360 (10)			376 (13)		328 (13)	333 (13)
High Resolution		370 (13)					361 (13)	
Morse-Maneuverable		386 (13)						
3rd Generation					364 (10)			
High Resolution								
2-tone Maneuverable					383 (13)			

TABLE 6–11.—SOVIET MILITARY PHOTOGRAPHIC RECOVERABLE KOSMOS MISSIONS BY KOSMOS NUMBER AND DAYS DURATION—Continued

	Launch Site and Inclination							
	Tyuratam			Plesetsk				
Year and category	51–52°	65°	69–71°	62–63°	65–66°	67°	72–73°	81°
1971								
3rd Generation	428 (12)	410 (12)			443 (12)			
Low Resolution								
PDM—Science								
3rd Generation	431 (12)	392 (12)			439 (11)			403 (12)
Low Resolution								
PDM								
3rd Generation	420 (11)	399 (14)			396 (13)		401 (13)	406 (10)
High Resolution	429 (13)	441? (12)			424? (13)			
Morse-Maneuverable	432 (13)	452? (13)			430 (13)		456 (13)	
		463 (5)			454? (14)		464? (6)	
		466 (11)						
3rd Generation		390? (13)			438 (13)		427 (12)	
High Resolution							442? (13)	
2-tone maneuverable								
3rd Generation					470 (10)			
Low Resolution								
2-tone Science								
1972								
3rd Generation					490 (12)		477 (12)	484 (13)
Low Resolution					525 (11)		518 (9)	
PDM—Science								
3rd Generation		473 (12)			512 (12)			
Low Resolution		493 (12)						
PDM		517 (12)						
		537 (12)						
3rd Generation	499 (9)	471 (13)	519 (10)		478 (13)		483 (12)	486 (13)
High Resolution		474 (13)			495? (13)		522 (13)	
Morse-Maneuverable		491 (14)			503 (13)			
		492 (13)			538 (13)			
		513 (13)						
3rd Generation					488 (13)		515 (13)	
High Resolution					527 (13)			
2-tone-Maneuverable								
3rd Generation					502 (12)			541 (12)
Low Resolution								
2-tone Science								
1973								
3rd Generation					561 (12)		552 (12)	555 (12)
Low Resolution								
PDM-Science								
3rd Generation		547 (12)			575 (12)			
Low Resolution		583 (13)			578 (12)			
PDM		599 (13)			596 (6)			
3rd Generation	572 (13)	543 (13)	609 (13)		548 (13)		560 (13)	
High Resolution	581 (13)	551 (14)			563 (12)		584 (14)	
Morse-Maneuverable					577 (13)		598 (6)	
					579 (13)		600 (7)	
							603 (13)	
3rd Generation					550 (10)		554 [*]	556 (12)
High Resolution					559 (5)		602 (9)	
2-tone Maneuverable					597 (6)		607? (8)	
					587 (13)		612 (13)	
							625 (13)	
3rd Generation							576 (12)	
Low Resolution							616 (11)	
2-tone Science								
1974								
3rd Generation				629 (12)			635 (12)	669 (13)
Low Resolution				692 (12)				
PDM-Science				697? (12)				
3rd Generation		658 (12)		653 (12)			696 (12)	640 (12)
Low Resolution		685 (12)						
PDM								
3rd Generation		632 (14)						
High Resolution		667? (13)						
Morse-Maneuverable								
3rd Generation	652 (8)	636 (14)	701 (13)	649 (12)			630 (14)	639 (11)
High Resolution		674 (9)		657 (14)			694 (13)	
2-tone Maneuverable		691 (12)		659 (13)				
				666 (13)				
				671 (13)				
				688 (12)				
3rd Generation							664 (12)	693 (12)
Low Resolution								
2-tone Science								

TABLE 6–11.—SOVIET MILITARY PHOTOGRAPHIC RECOVERABLE KOSMOS MISSIONS BY KOSMOS NUMBER AND DAYS DURATION—Continued

	Launch Site and Inclination							
	Tyuratam			Plesetsk				
Year and category	51–52°	65°	69–71°	62–63°	65–66°	67°	72–73°	81°
1975								
3rd Generation		731 (12)		747 (12)			728 (11)	721 (12)
Low Resolution		780 (12)		776 (12)			769 (12)	784 (12)
PDM-Science								
3rd Generation			702 (12)	751 (12)				741 (12)
Low Resolution								
PDM								
3rd Generation		710 (14)	722 (13)	709 (13)		758 [*]	704 (14)	730 (12)
High Resolution		719 (13)	754 (13)	742 (12)				771 (13)
2-tone Maneuver-able		727 (12)	774 (14)	743 (13)				
		740 (13)		746 (13)				
		760 (14)		748 (13)				
		786 (13)		753 (13)				
				757 (13)				
				779 (14)				
3rd Generation				720 (11)				
Low Resolution				759 (11)				
2-tone Science								

NOTES

1. This table includes all military recoverable observation flights for photographic reconnaissance which may also serve other military information gathering purposes.

2. Flights are grouped by year, by each of three major generations, by probable camera resolution category, and by telemetry format. Flights are further listed by general orbital inclination, and the number of days duration for each flight is also shown.

3. Certain flights apparently could not be recovered through retrofire to bring them to the Soviet recovery area, generally in Kazakhstan, and these were exploded in orbit, presumably on command. These flights are marked [*] instead of giving the number of days to recovery.

4. First generation flights were defined as those launched by the A–1 class vehicle, and most flew for about 8 days. Second generation flights were presumably heavier, because they used the A–2 launch vehicle, and they also typically flew for 8 days until recovery. When these second generation flights first appeared, they presumably were able to take photographs of higher resolution than the first generation flights. Later, the second generation flights were supplemented by equally heavy payloads which took lower resolution pictures. It is probable that the first and second generation flights used the basic Vostok/Voskhod recoverable shell and service module. A third generation appeared with flight durations most typically of 12 or 13 days, and these are divided into a variety of subtypes. The first to appear were of lower resolution, and often carried supplemental pickabacks. They were identifiable by pulse duration modulation (PDM) signals. Second, came maneuverable satellites, presumably of higher resolution. They were also distinguished by a "Morse code" signal format. These have been replaced by a third subtype in the third generation which also maneuver and are presumed to be of higher resolution, but their signal format is two-tone, without telemetry on the usual frequencies. Beyond these main families are various other combinations of flights whose frequencies or telemetry format is contradictory. For example one group are two-tone like the maneuverables, but use the frequency also used by the PDM flights; they do not maneuver, yet cast off a capsule. A very few more fit other categories as labeled in the table, but there have not been enough of these to find regular patterns to them. The third generation flights may use a Soyuz recoverable shell and Soyuz service module but there is no direct evidence. The "capsule" they cast off may be a modification or replacement of the work module used by Soyuz. They may use chemical batteries rather than solar panels.

5. There are acute problems of making assignments to categories because of gaps in data or contradictory information. These tables are based primarily on the work of the Kettering group. For the years 1962–1970, the tables are largely as reported in the 1966–70 report for the Senate corresponding to this study, which were developed with the help of Kettering. For the 1971–1975 period, the tables are basically as assembled by the Kettering group with all departures from such assignments indicated in these notes. Where Kettering lacked information, and estimates have been made to assign this minority, each flight number is followed by a question mark to make clear that either other data were used or the assignment is a guess, and sometimes not as conservative as the Kettering findings based upon actual telemetry received and interpreted by them.

6. Where a subgroup includes the label "Science" as part of the designation, either the Russians ultimately announced a scientific experiment, or the telemetry formats and visual or radar observations showed a pickaback was cast loose that was not a maneuvering engine. Other exceptions are coded "B" for biological, "W" for weather, or "S" for science. All other anomalies and points in disagreement are tabulated below:

1962: Kosmos 4, 7, and 9 apparently carried supplemental experiments, 4 and 7 gathering biological data, probably of radiation, and all three gathering some weather-related data.

1963: Kosmos 15 gathered some weather-related data.

1964: Kosmos 50 after 8 days of flight could not be recovered and was exploded. Kosmos 45 carried a supplemental weather reporting experiment.

1965: Kosmos 65 and 92 carried supplemental weather reporting experiments. Kosmos 92 and 94 carried supplemental biological experiments.

1966: Kosmos 109 carried a supplemental biological experiment. Kosmos 134 and 136 carried supplemental scientific experiments.

1967: Kosmos 143 carried a supplemental scientific experiment.

1968: Kosmos 224 carried a supplemental scientific experiment. Kosmos 232 carried a weather experiment. Kosmos 199 could not be recovered at the end of eight days of flight and was exploded.

1969: Kosmos 274 carried a supplemental scientific experiment. Kosmos 293 is listed with the group which carried a scientific pickaback, based upon its telemetry, even though no separated pickaback was detected later in the flight. Kosmos 309 looked like a second generation flight with its eight days in orbit, but its telemetry revealed it was third generation.

1970: No anomalies.

1971: There were seven flights Kettering could not allocate for certain. Kosmos 424, 441, 452, 454, and 464 all maneuvered and cast loose maneuvering engines; they have been grouped with the "Morse code" group based upon the preponderance of evidence. Kosmos 390 and 442 cast loose maneuvering engines, and the preponderance of evidence in these two were of the "two-tone" group.

1972: Kettering did not assign Kosmos 495, and it has been grouped with the "Morse code" group based upon the preponderance of other evidence.

1973: Kosmos 554 was exploded after sixteen days when recovery earlier had failed. Kosmos 596 was difficult to classify: Kettering did not detect a pickaback through telemetry, yet at an intermediate point in the flight, recovery signals were heard suggesting a possible early recovery of a capsule; some kind of a capsule was listed in orbit by the RAE report. Kettering did not assign Kosmos 607, and it has been put in the two-tone group on the basis of the preponderance of evidence.

1974: Kosmos 667 was not assigned by Kettering; the preponderance of evidence puts it in the "Morse code" series. Kosmos 697 was not assigned by Kettering, but the preponderance of evidence seems to point towards its also being a PDM low resolution flight with scientific pickaback, and a capsule was reported by the Royal Aircraft Establishment (RAE).

1975: Kosmos 758 is almost impossible to classify: It flew at a unique inclination, and was exploded after a little more than four days of flight. It possibly was the first of a fourth generation of observation satellites.

7. Recovery beacons represent another and generally consistent way of sorting out these missions into the same groupings. The observations of these beacons by the Kettering Group have been compiled and are listed by beacon, in the same order as the flights in the table, with question marks if the signal was in doubt.

TK: 126, 127, 114, 155, 182, 150, 161, 190, 194, 141, 175, 227, 234, 201, 207, 232, 237, 241, 246, 228, 208, 279, 284, 288, 267, 274, 296, 299, 270, 271, 282, 286, 294, 302, 297, 276, 293, 306, 313, 280, 345, 352, 322, 323, 349, 355, 318, 370, 376, 328, 333, 420, 432, 396, 401, 499, 492, 513?, 519, 503, 483, 561?, 572, 581, 609, 548, 579?, 584, 771.

TG: 278, 290, 325, 344, 384, 350, 428, 431, 518, 484, 473, 493, 517, 561?, 575, 578, 596, 629, 635, 696, 658, 685, 653, 640, 728, 702, 751, 776.

TU?: 329.

TF: 383, 317?, 587, 691, 701, 657, 659, 688, 710, 719, 754, 774, 742, 748, 704, 779.

TL: 541, 576, 664.

SOURCES: The basic list of flights, their inclinations, and durations are from Appendix A, that is, Soviet TASS bulletins plus decay data from the Royal Aircraft Establishment (RAE). The classifications are primarily based upon the work of the Kettering group which opened in the public domain the whole exploration of categories. Resolutions are inferred from persistent patterns in telemetry from one group to another, matched against whether maneuvers occurred in the third generation. Scientific pickabacks and maneuvering engines are all listed as "capsules" by the RAE. At first, pickabacks were revealed in the followup Soviet scientific literature, and now this disclosure seems to have ceased. Hence, the label "scientific" may encompass today military supplemental payloads whose hardware handling is not unlike the earlier science hardware. With the help from the Kettering group for understanding the patterns of frequencies and telemetry formats, then some additional assignments could be made either firmly or tentatively even in the absence of direct Kettering radio intercepts.

TABLE 6-12.—SUMMARY OF SOVIET MILITARY PHOTOGRAPHIC RECOVERABLE KOSMOS BY YEARS AND BY GENERATION AND SUBCATEGORY

Year	First Generation	Second Generation		Third Generation					Total
	Low resolution	High resolution	Low resolution	Low resolution, PDM	Low resolution, PDM, science	Low resolution, 2-tone science	High resolution, Morse maneuvered	High resolution, 2-tone maneuvered	
1962	5								5
1963	6	1							7
1964	9	3							12
1965	7	10							17
1966	9	10	2						21
1967	5	9	8						22
1968		13	12		3		1		29
1969		17	8	2	2		2	1	32
1970		8	3	7	2		7	2	29
1971				4	3	1	16	4	28
1972				5	5	2	14	3	29
1973				6	3	2	14	10	35
1974				5	5	2	2	14	28
1975				3	8	2		21	34
Total	41	71	33	32	31	9	56	55	328

NOTE

This table summarizes the data contained in the many pages of the immediately preceding table, and has pulled together counts on a single page to make it easier to comprehend the trends of the more complex table.

SOURCES: Table 6-11, preceding.

67-371—76——30

TABLE 6-13.—SUMMARY OF SOVIET MILITARY PHOTOGRAPHIC RECOVERABLE KOSMOS BY YEARS AND BY ANNOUNCED INCLINATION

	Tyuratam												Plesetsk															
Year	51.3	51.6	51.7	51.8	51.9	64.9	65.0	65.1	69.0	70.0	71.3	71.4	62.8	64.6	65.0	65.4	65.6	65.7	67.1	72.0	72.8	72.9	73.0	81.2	81.3	81.4	Total	Grand Total
1962—A-1							5																				5	5
1963—A-1							6																				6	7
1963—A-2						1																					1	
1964—A-1	4						3	2																			9	12
1964—A-2						2	1																				3	
1965—A-1							6		1																		7	17
1965—A-2				2		1	7																				10	
1966—A-1							6							1	1					1							9	21
1966—A-2				3	1		5															2	1				12	
1967—A-1	1						1							1	2												5	22
1967—A-2				5			1										1	7				3					17	
1968—A-2		1		7			5				1				1	7	1	2			1	1		1		1	29	29
1969—A-2		1		5			6			1					1	15						2				1	32	32
1970—A-2				4			9								1	8						4			1	2	29	29
1971—A-2				5			8									8						5			1	1	28	28
1972—A-2				1			9				1					10						5			1	2	29	29
1973—A-2		1	1				5			1						12					1	12			2		35	35
1974—A-2				1			7					1	10									5			4		28	28
1975—A-2							8					4	13						1		1	2			4	1	34	34
Totals:																												
A-1	5						27	2	1					2	3					1							41	
A-2		3	1	33	1	4	71			2	2	5	23		3	60	2	9	1		3	41	1	1	13	8	287	
Grand total	5	3	1	33	1	4	98	2	1	2	2	5	23	2	6	60	2	9	1	1	3	41	1	1	13	8	-----	328

NOTES

1. Because Tables 6-11 and 6-12 grouped flight inclinations by general categories, obscuring possible subtleties of differences, this table lists the actual inclinations announced by the Russians, and further, shows separate counts for A-1 and A-2 launch vehicles for each year. While A-1 and A-2 designations are based primarily upon radar and optical evidence (since the A-2 carrier rocket is about three times as long as the A-1 carrier rocket) this table also shows that inclination in some cases correlates with the launch vehicle used. For example, all 51.3° flights used the A-1, and a 51.6° flights used the A-2.

SOURCES: From Soviet TASS launch bulletins, as summarized in Appendix A.

1. Flight Durations

While during the first year, the average duration of flights was 4.6 days, this quickly stabilized for the next seven years at about 8 days. Then 12 and 13 day flights were phased in, and the average for all the more recent years has been around 12 days. A few flights stay up 14 days. Those brought back in shorter times in a few cases may reflect malfunctioning equipment, but more often seem to be associated with crisis situations where a quick look for order of battle makes it more important to have pictures in hand than to obtain maximum use from the payload. As explained earlier, if it is impossible to orient the flight for recovery or if retrofire fails, the payload is exploded to prevent its random decay in some place outside Soviet territory in nearly intact form.

2. Launch Sites

From 1962 on, flights have come from Tyuratam, and in 1966 Plesetsk was also brought into use, now being the more commonly used of the two sites. No obvious reason is evident, nor is there any regular pattern visible in the switch of launches back and forth between the two sites.

3. Inclinations

Tyuratam alone is used to send flights to inclinations around 52 degrees. Plesetsk alone is used to send flights to about 81 degrees. Now both sites come close to duplicating each other's coverage in the range from 62 to 73 degrees.

Usually a pair of flights is sent each spring to about 81 degrees latitude, presumably to give coverage of the ice movement along the Northern Seas Route across the top of Eurasia. The Kettering Group has also demonstrated that sending summer flights at about 52 degrees will give some twice-daily coverage of northern hemisphere target areas of interest, during good daylight hours.[40]

Some of the other reasons for choice of inclination are to cover areas of interest either as soon as possible after launch, or with the right lighting conditions, or to be timed to match some ground event.

The immediately preceding table (6–13) showed that some of the slight differences in inclinations that are similar can be correlated with use of either the A–1 or the A–2 launch vehicle. One can imagine that perhaps with a pair of launch pads at a given site, originally both intended for the A–1 vehicle, that one was adapted first for use with the taller A–2 rocket, by adding extra service platforms at greater height, and this shift to a particular pad then showed up for a time in the inclinations attained because of the guidance techniques used during the launch phase. Later, the second pad was also adjusted, as the last of the A–1's was withdrawn from that part of the program, again reflected in inclinations as the A–2's came into greater use.

4. Altitudes of the Flights

These summary tables did not include information on the altitudes of the flights, which details are carried, however, in Appendix A, the master log of all flights. One reason is that there seems no discernible pattern that ties variations in altitude to camera systems or stay time

[40] Perry, G. E., Spaceflight, London, *14* May 1972, p. 184.

in orbit. Apogees have ranged from 236 kilometers to 415 kilometers, with 300 to 350 probably most typical. Perigees have ranged from 147 kilometers to 298 kilometers with 200 to 210 probably most typical.

The later generation maneuverable satellites now sometimes lower their perigees during flight which may be to improve resolution, and may require additional maneuvers to maintain the flight for its full length.

A probable reason for some differences in altitude is to supplement variations in flight inclination as a way of producing a ground trace which will pass close to targets of interest for observation.

5. Identification of Variants

The separation between the first and second generation flights was possible because the A–2 rocket is about three times as long as that of the A–1 when this final stage is discarded in orbit. Optically, the difference in stellar magnitude makes it possible to distinguish the two sizes, and radar analysis provides more specific measurements.[41] The inference has been that the second generation payloads which are put up by a more powerful upper stage probably have an improved camera system that would permit higher resolution pictures.

Among the second generation A–2 flights, two telemetry modes appeared, and the flights were intermixed. The tentative assumption was that there might be two different degrees of resolution, with perhaps the simpler camera systems leaving weight and space over for carrying other sensors to permit synoptic measurements of military interest. This hypothesis which at first was hard to prove from public evidence in time received added support when the third generation flights appeared. There were similar differences and cross links in telemetry patterns suggesting a continuity of function, and the third generation flights definitely could be sorted into maneuvering and non-maneuvering payloads, strengthening the implication that fine maneuvers were to position high resolution cameras, while absence of maneuver was more likely to mean wider area coverage in search missions at lower resolution before the detailed study at high resolution.

As to the payloads themselves, they have not been put on display. From the general launch patterns and orbital behavior, the assumption has been that the first and second generation military observation flights were probably using essentially the same system as Vostok/Voskhod, which even though manned, operated either automatically or by ground control, so that a minimum change in the hardware for the vehicle bus and service module would be required in moving from the manned program to the unmanned military flights.

What is less clear is whether the third generation flights which typically stay up 12 or 13 days also use Vostok/Voskhod hardware, or whether the program has graduated to Soyuz-related hardware. The advantage of the Soyuz system would be greater ability to maneuver, and the development of some lift during the reentry phase, because of the change of shape of the reentry body. Since many of the third generation payloads cast loose a "capsule" (to use the RAE

[41] Pilkington, J. A., Flight International. London, 86 October 1, 1964. 605–607.

terminology), this may represent either a modification of the work compartment carried by Soyuz or more specialized hardware that fits in the same place. There have been no confirmed reports of gull-like solar panels on these third generation flights, so they may use chemical batteries as do the manned Soyuz ferry craft of the present period. However Geoffrey Perry and David Hawkins observed Kosmos 599 to be brighter than most earlier satellites of the recoverable series.

The first generation flights seemed to have only one basic family. The second generation flights had two basic types, of differing resolutions. All three of these families might on occasion carry a supplemental scientific or technical experiment. (These have been tabulated in Tables 2–4 and 6–11.) But the third generation flights have proliferated into at least five major families or subgroups, and a few additional flights either are anomalous or contradictory, and not enough evidence has been gathered to supply an adequate interpretation of the reasons for their differences.

While the third generation flights use the A–2 and may use a modified Soyuz, the identification of types can be approached several ways. General tracking evidence reveals whether or not they maneuver, and whether or not they cast loose late in the flight a portion of the payload which usually in a few days decays without any attempt at recovery in the Soviet Union. As suggested, maneuvering ships are more likely high resolution systems.

A second approach to sorting out the types relates to the frequencies on which they send back telemetry. A third approach has to do with the signal formats of the telemetry. A fourth approach relates to the recovery beacon code. Because data are not always available in the public domain in every one of these categories, it requires combining as many as possible and in most cases like identification from a partial fingerprint, it is possible to get a fairly positive identification of the mission. When a particular flight is anomalous in some degree, one has to ask whether data are being misinterpreted, or whether there has been a partial flight failure, or whether still another new variant has appeared on the scene.

On the basis of these several indicators, the third generation flights seem to divide up as follows: (1) Those whose telemetry is usually of the PDM (pulse duration modulation) type, most typically broadcasting on 19.994 MHz, and whose recovery beacon is typically the Morse signal, "TG". These typically 12-day duration flights do not maneuver. If word 7 of the telemetry close to the time of launch is short, and suddenly lengthens, then the main satellite releases a supplemental payload toward the end of the flight, which supplemental payload decays in a few days. If word 7 is very long from the outset, there is not a supplemental payload separated. (2) Those whose telemetry is usually of "Morse code" in a series of three "letters" which actually are quantitative data in binary form, and these most typically broadcast in 19.150 MHz, and their recovery beacons send back the Morse letters "TK", either on 19.995 or 20.005 MHz. These flights maneuver, and cast loose the maneuvering engine late in the flight which usually last 13 days. These flights have now been phased out. (3) Those which emit two-tone signals on about 19.989 MHz, but have no detectable telemetry at this frequency. When these are recovered, their

beacon broadcasts the letters "TF". These flights maneuver, and typically last 13 days. An additional class are flights which also use two-tone signals without telemetry, but do not maneuver. They broadcast on 19.994 MHz like the PDM flights and have a TL recovery beacon. They cast loose an object toward the end of the flight, so the assumption is they are low resolution with some kind of science payload.

Every PDM payload which separated a pickaback with a Kosmos number up through all of the 400 series has subsequently been identified by the Russians as conducting scientific work, but all such numbered 500 and above have not. Of the two-tone, non-maneuvering flights using the PDM frequency, and casting loose a pickaback, the first was Kosmos 470, and it has not been identified by the Russians as doing scientific work; nor have they identified any others of this subset with numbers above 500 as doing scientific work.

Finally, there have been a few flights, not yet well enough understood to label conclusively, which fit classes listed above, but they seem to have associated with them during the flight "TK" signals as if they were about to be recovered, yet they fly on for their full appointed number of days. This raises the question of whether like Salyut 3 they are making an early return of a film carrying capsule which is recovered, in contrast to the pickabacks which are cast loose merely to decay through air drag. If this is so, it would make sense to permit a quick look at early coverage without terminating the whole mission which could continue for additional days to photograph other targets.

Three remaining observations: (1) A reminder that labeling a supplemental or pickaback "scientific" in the context of these flights is only to reflect the fact that for the first years after 1968 when such extra experiments appeared they were identified by the Russians as geophysical or biological. However, since mid-1972, not a single additional identification has been supplied, so the label may be a misnomer if their function has become military. (2) Flights identified on the basis of having a frequency of 19.994 or 19.995 MHz may suddenly switch to 19.989 or 19.990 MHz to clear the first frequency for a second launch which is about to go up before the former one has been recovered, so that identification of group by frequency requires finding the frequency at the right time during the flight before conclusions can be drawn about categorizing the mission. And (3), a word about two main families of supplemental experiments: From the earliest days of the military observation recoverable flights, a number of them carried extra experiments, but cast loose no pickaback. Presumably, if these were using the Vostok/Voskhod hardware, the experiment was probably contained within the recoverable cabin. Today, most but not all supplemental experiments seem to be linked with a separate compartment which is cast loose, and this is a factor strengthening the notion that the Soyuz hardware is being used, but this is anything but conclusive. Even now, some supplemental experiments may be carried by the same third generation hardware which may be Soyuz related, and yet what most often is cast loose is a maneuvering engine. This suggests that as with the early flights, the supplemental experiments are returned to Earth in the main cabin, rather than cast off in orbit to decay through air drag. However, these interpretations are only speculative.

G. SUMMARY OF COMMITMENT OF LAUNCHES AND PAYLOADS TO MILITARY VERSUS CIVIL PRIMARY USES

This chapter has reviewed the principal probable military uses of space by the Soviet Union, examining each mission and candidate group of flights, if any, which seem to come closest to being the probable agents of execution. Now it is time to summarize in tabular form the general division of activity between civil and military, with all the caveats which have been carried in the text to this point. For the sake of comparison, corresponding figures have been developed for the United States, and the division in the latter case is not just between NASA and DoD, because some missions in the past could as easily have been done by either principal agency. Rather, the attempt has been to look at those missions which have broad scientific and civil applications, and which are generally readily discussed in press releases of both the United States and the Soviet Union, to contrast these flights with others in which both governments show considerable reticence. As explained, in the Soviet case, these make up the largest part of the Kosmos program. In the U.S. case, these are flights which carry no names and no details beyond the fact of launch. Such a table is necessarily arbitrary and subject to argument, but has been evolving over the years with sufficient time to test that as a simple count, without value judgments and special weighting, it is generally indicative of the division of launch and payload effort. Table 6–14 follows.

TABLE 6-14.—APPROXIMATE COMPARISON OF UNITED STATES AND SOVIET SUCCESSFUL SPACE LAUNCHINGS AND PAYLOADS PRIMARILY CIVIL-ORIENTED VERSUS PRESUMPTIVELY MILITARY-ORIENTED

Year	Launches							Payloads							
	United States				U.S.S.R.			United States				U.S.S.R.			
	NASA civil	DOD civil	DOD military	Total	Civil	Military	Total	NASA civil	DOD civil	DOD military	Total	Civil	Tyazheliy Sputnik	Military	Total
1957					2		2					2			2
1958		5		5	1		1		5		5	1			1
1959	5		5	10	3		3	5		5	10	3			3
1960	5	1	10	16	3		3	5	2	10	17	3			3
1961	10		19	29	6		6	10	6	19	35	6	2		8
1962	18	1	33	52	15	5	20	19	7	33	59	15	6	5	26
1963	10	2	26	38	9	8	17	11	19	32	62	9	3	8	20
1964	22	2	33	57	13	17	30	23	10	40	73	15	4	20	39
1965	23	7	33	63	19	29	48	29	31	37	97	19	11	45	75
1966	30	9	34	73	16	28	44	30	27	44	101	16	8	28	52
1967	25	6	26	57	20	46	66	26	30	32	88	20	9	46	75
1968	19	4	22	45	22	52	74	21	16	27	64	25	8	52	85
1969	21	3	16	40	17	53	70	26	15	25	66	19	8	53	80
1970	12	1	16	29	26	55	81	17	3	19	39	29	12	62	103
1971	14	4	13	31	21	62	83	20	16	17	53	28	10	76	114
1972	17	1	13	31	19	55	74	23	2	16	41	28	12	69	109
1973	12	1	10	23	27	59	86	12	2	12	26	34	15	80	129
1974	14		8	22	26	55	81	16		12	28	34	11	69	114
1975	18	1	9	28	27	62	89	21	3	10	34	40	16	83	139
Total	275	48	326	649	292	586	878	314	194	390	898	346	135	696	1,177

SOURCE: Derived synergistically between Appendix A and text of this report.

CHAPTER SIX ANNEX ONE

NAVIGATION SATELLITES

By Geoffrey E. Perry*

I. An Operational System With A 74° Inclination

Kosmos 378 was the first satellite of this inclination to have an initial period of 105 minutes. This was placed in an elliptical orbit from which it has already decayed. The Soviet report to the 14th COSPAR session stated that it had performed ionospheric research.[1] Shortly afterwards, Kosmos 381 was placed in a near-circular orbit with a period of 105 minutes. Sven Grahn reported receiving inonospheric beacon-type signals in Stockholm and Geoffrey E. Perry found similar signals on a higher frequency in Kettering as well. A statement that "Kosmos 381 was probing the ionosphere" implied a top-side-sounder of the Alouette-Isis type, together with other techniques.[2] A full-scale model was displayed at the 1971 Paris Air Show. This was a cylinder 1.4 meters tall and 2.0 meters in diameter. The curved surface was covered with solar cells. Gravity-gradient stabilization appears to have been used with the long beam reaching up to the roof of the hall. For a satellite of this size equipped with solar batteries the transmitting life was exceptionally short, last signals being received in Kettering on January 30, 1971. Fears that absence of further signals was due to lack of perseverance in monitoring were dispelled by the Soviet report to the 15th COSPAR conference which stated that "Kosmos 381 studied VLF signals in the magnetosphere from December 2, 1970 to January 30, 1971."[3] It may be that other experiments continued functioning beyond that date, however.

Ten days after the launch of Kosmos 381, Kosmos 385 was placed into a similar orbit. No ionospheric beacon signals from this satellite were detected by the Kettering Group. This was followed at intervals throughout 1971 by Kosmos 422 and 465 and by Kosmos 475 and 489 in the early part of 1972. There have been no other launches of this type since then.

TABLE 6A1-1.—LIST OF SOVIET NAVIGATION SATELLITES AT 74°, 1970-1972

Satellite	Initial orbital elements: Period (min)	Apogee (km)	Perigee (km)	Right ascension of ascending node on May 6, 1972 (degrees)	Launch date
Kosmos 385	104.8	986	978	157	Dec. 12, 1970
Kosmos 422	105.1	1,010	988	37	May 22, 1971
Kosmos 465	104.9	1,012	970	278	Dec. 15, 1971
Kosmos 475	104.8	1,000	970	158	Feb. 25, 1972
Kosmos 489	104.8	1,000	969	39	May 6, 1972

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1 Shtern, M. I., Investigations of the Upper Atmosphere and Outer Space Conducted in 1970 in the U.S.S.R. (translated by NASA in 1972). p. 28.

2 Soviet News, January 12, 1971.

3 ———. Investigation of the Upper Atmosphere and Outer Space Conducted in 1971 in the U.S.S.R. (translated by the Joint Publications Research Service in 1972). p. 29.

The position of the orbital plane in space relative to the fixed stars is specified by the right ascension of the ascending node or north-bound Equator-crossing. For a given satellite the rate of change of right ascension remains fairly constant over long periods of time. It is therefore possible to compute values of right ascensions for given epochs if this rate of change and the value of right ascension at a fixed epoch are both known. In 1972, Perry employed this technique to show that these satellites are in orbital planes spaced at 120° intervals.[4] This is evident from the table given above which shows the values of right ascension for each satellite on the launch date of the last in the group. This configuration provides the rudiments of global coverage.

Moreover, it will be seen that the orbital planes of Kosmos 475 and 385 coincide, as do the planes of Kosmos 489 and 422. It is therefore reasonable to assume that Kosmos 475 and 489 replaced Kosmos 385 and 422 respectively after intervals of 440 and 350 days, pointing to a useful payload life of about one year.

II. The Change to 83° Inclination

An inclination of 83°, the highest used to date by the Soviet Union, first appeared with the launch of Kosmos 480 into a 109 minute orbit on March 25, 1972. Kosmos 514, also at this inclination, had a period of 104.4 minutes reminiscent of the 74° navigation satellites. It has been followed at regular intervals by Kosmos 574, 586, 627, 628, 663 and 689.

Using a graphical method, Perry and Ian Wildman of Kettering Grammar School were able to show that these satellites also had orbital planes spaced at regular intervals but that the spacing in this instance was only 60°.[5] From their work it was apparent that Kosmos 627 had replaced Kosmos 514, Kosmos 689 had replaced 574, and that Kosmos 586 had been replaced in turn by Kosmos 628 and Kosmos 663.

Kosmos 700, launched at the end of 1974, did not fit the general pattern of replacement. Its orbital plane was offset from the main system by 20° to the east of Kosmos 627. Kosmos 726, the next member of the sub-set, was again offset from the main system and spaced 120° from Kosmos 700. The obvious gap in this supplementary system was filled by Kosmos 755, placed mid-way between these two. In the meantime Kosmos 729 had replaced Kosmos 627.

The launch of Kosmos 778 on November 4, 1975, signalled a new development. Offset 30° to the east of Kosmos 726, it marked the beginning of a transitionary phase toward 30° spacings based on the supplementary system and the eventual disappearance of the original main system. Kosmos 789, launched on January 20, 1976, was the second of these and was placed midway between Kosmos 700 and 755, presumably replacing Kosmos 689.

III. The Radio Transmissions

When Christopher Wood returned to the United Kingdom from Fiji, Perry encouraged him to try to identify the radio transmissions

[4] Perry, G. E., Flight International, London, *102*, 788a–790, November 30, 1972.
[5] Perry, G. E., and C. D. Wood, Journal of the British Interplanetary Society, 29, 307–316, 1976.

from this group of satellites. Observations on 150 MHz, one of the frequencies known to be used by the U.S. Navy navigation satellites, suggested that this frequency was also used by the Kosmos satellites. Positive identification was made by showing that times of closest approach from Doppler measurements in Oxted, just south of London, showed a close correlation with predictions based on Goddard Space Flight Center two-line orbital elements. W. F. Blanchard has since established that these satellites also transmit on 400 MHz, another of the U.S. Navy frequencies.[6]

Wood was able to show that two types of signal, designated type A and type B for convenience. existed. Both types contain data at 50 bits per second but employ different modulation methods and bandwidths. The modulation methods result in sidebands symmetrically disposed around the 150.000 MHz carrier (U.S. Navy satellites use a frequency of 149.988 MHz to prevent operation near nulls on crossovers which would reduce accuracy). Type A has five pairs of sidebands at 3 kHz intervals spaced at 14 kHz from the carrier whereas type B has three pairs of sidebands at 2 kHz intervals spaced 3 kHz from the carrier. Wood has shown that this prevents mutual interference when signals are received simultaneously from two satellites, even allowing for opposite Doppler shifts.

His detailed analysis of the type B transmissions has shown that the telemetry frame consists of 60 words of 1 second duration, each containing 50 bits. Three different types of words are used. The first bit of each word occurs on an exact second synchronized with standard time transmissions from WWV. Bits 2–6 of each word form a block which decodes to give an hour count; bits 7–12 form a block which decodes to give a minute count and bits 13–18 decode to give a second count. The code is a development of the normal binary code—the difference between successive received bits giving the normal binary code. In this way Perry and Wood have shown that the transmitted time is Moscow Time—GMT plus 3 hours.

The telemetry frame of the type A transmissions consists of only ten 1 second, 50 bit words of which the last three contain only time data. Moreover, only two different types of words are employed. It is of interest to point out that the main and supplementary systems disclosed by Perry and Wildman's analysis of orbital plane position correlate exactly with the type A and type B signals distinguished by Wood.

A third type of transmission has been received from the latest satellite. Kosmos 778. Since it features the two-frequency f.s.k. (frequency shift keyed) modulation of type B rather than the four-frequency f.s.k. modulation of type A, it has been classified as type B′. Preliminary study suggests a basic 2 minute frame comprising two 1 minute frames of differing types, using all three types of word found in the type B transmissions.[7]

IV. Conclusion

The two fundamental requirements for an operational navigation satellite system—global coverage and standard time transmissions—have been shown to exist within a sub-set of the Kosmos program. The six-satellite system currently operational, with orbital plane spacings

[6] Blanchard. W. F., private communication.
[7] Wood, C. D., private communication.

in parens is: Kosmos 729 (20°) Kosmos 700 (40°) Kosmos 689 (20°) Kosmos 755 (40°) Kosmos 663 (20°) Kosmos 726, with transmission types in the sequence A B A ? A B. Signals from Kosmos 755 have still to be identified and are expected to be of type B. A seventh satellite, Kosmos 778, has recently been placed 30° beyond Kosmos 726 with a new type of transmission, type B′, which would appear to mark the start of a transition to a 30° spacing between operational satellites. Kosmos 789 was placed midway between Kosmos 700 and 755 in the early part of 1976 and it is expected that Kosmos 663 will soon be replaced by a satellite spaced 30° from Kosmos 755 and 726.

TABLE 6A1-2.– LIST OF SOVIET NAVIGATION SATELLITES AT 83°, 1972-1975

Satellite	Initial orbital elements			Right ascension of ascending node on Nov. 4, 1975 (degrees)	Transmission type	Launch date
	Period (min)	Apogee (km)	Perigee (km)			
Kosmos 514	104.4	975	958	44		Aug. 16, 1972
Kosmos 574	105.1	1,014	985	114		June 20, 1973
Kosmos 586	104.9	1,009	971	171		Sep. 14, 1973
Kosmos 627	105.1	1,019	974	52	A	Dec. 29, 1973
Kosmos 628	104.9	1,016	958	172		Jan. 17, 1974
Kosmos 663	104.9	1,007	972	173	A	June 27, 1974
Kosmos 689	105.1	1,017	981	114	A	Oct. 21, 1974
Kosmos 700	104.8	999	966	71	B	Dec. 26, 1974
Kosmos 726	104.7	996	956	194	B	Apr. 11, 1975
Kosmos 729	105.1	1,011	980	53	A	Apr. 22, 1975
Kosmos 755	105.0	1,013	974	132		Aug. 14, 1975
Kosmos 778	105.0	1,004	978	224	B′	Nov. 4, 1975

CHAPTER SIX ANNEX TWO

RECOVERABLE KOSMOS SATELLITES FOR MILITARY RECONNAISSANCE

By Geoffrey E. Perry*

I. Launch Statistics

On March 16, 1962, the Soviet Union initiated the Kosmos program "to continue the study of outer space". When it was announced that Kosmos 4 had been recovered from orbit after a flight of only four days it was clear that the name Kosmos was a blanket-term covering a variety of missions. A systematic study of the orbits, launch-times, launch-sites, locations of perigee, flight duration, and routine monitoring of short-wave radio transmissions, such as has been carried out at Kettering Grammar School since 1962, reveals distinct subsets, the largest of which contains those satellites which disappear from orbit when their orbital period is still high enough to rule out natural decay.

At the time of the launch of Kosmos 250, nearly 47 per cent of all Kosmos launches fell in this category. This proportion rose to over 50 per cent by the launch of Kosmos 350 but, with the change to longer duration flights, it decreased once more and, at the end of 1975, it stood at 47.19 per cent. Another way of looking at the statistics reveals that during 1975 at least one member of this subset was in orbit for 86.3 per cent of the time, two or more were in orbit simultaneously for 26.6 per cent of the time, and three in orbit for 11.0 per cent of the time.

Initially all such launches originated from Tyuratam but since the first launch from Plesetsk, in 1966, the majority of such launches have been made from there and in 1975 Plesetsk launched 22 of the 34 payloads in this sub-set.

II. Mission Profile

These satellites are launched by the A-vehicle in either its A–1 or, nowadays, A–2 configuration. Injection into orbit occurs some 9 minutes after lift-off and, when ionospheric conditions produce favorable propagation, short-wave radio signals can be received at this time.

Transmissions of this type are not continuous but cease after a predetermined time. They commence once more when commanded as the satellite rises above the horizons of Soviet ground-stations. In general they are not commanded-on for passes which do not take them directly over Soviet territory and it is not unusual, these days,

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for certain passes which do go over Soviet territory to fail to produce short-wave signals. As described later, VHF transmissions are commanded-on when the satellite is well above the horizon of the ground-station.

The first generation satellites utilized a switching sequence towards the end of their final transmitting pass of the day but this is rarely observed nowadays.[1] When a second satellite is to be launched during an uncompleted mission, the transmission frequency of the first satellite is changed by 2n Hz, where n Hz is the amount by which it is offset from either 19 MHz or 20 MHz, whichever is the nearer, in the first instance.

Throughout the final orbit before recovery the short-wave transmitter transmits continually, although Wakelin's observations in Cyprus have recently suggested that this may no longer be true. The round-the-whole-orbit transmission was established by Wood's observations from Fiji supplemented by early-morning observations during the mid-summer months in Kettering.

As far as one can tell, all payloads have been recovered on a northbound pass, including Kosmos 231, 720 and 759 which were recovered in darkness. An explanation for this is to be found in the recovery technique described for the manned Vostok spacecraft. While over Africa the position of the spacecraft was automatically orientated so that the vector of the retro-thrust was in the correct direction relative to the orbit. Doubtless optical sensors were used for this purpose and therefore sunlight was essential for their operation. Although these three satellites landed in darkness, retro-fire would have been in sunlight.

Wood's reception of signals from Kosmos 199 in Fiji indicated that recovery was planned on the eighth day and, although the payload was exploded the short-wave transmitter continued in orbit with a reduced period and transmitted until it decayed naturally several days later. Another recovery failure occurred in 1973 when Kosmos 554 was exploded just before the transmitter, which had operated continually following the abortive reentry attempt, failed due to exhaustion of the chemical batteries.[2]

Details of recovery and the signals received at those times are given in Section V of this Annex.

III. Photographic Coverage

Our first indication that these satellites might be more concerned with the collection of intelligence rather than the transmission of previously garnered data came during our second study of a satellite of this sub-set, Kosmos 15, in April 1963. We observed that it did not transmit on revolutions 19, 35, 51 and 67 when it was passing northbound across Great Britain.[3] I believe that, at about that time, the BMEWS (ballistic missile early warning system) station at Fylingdales was being commissioned.

By plotting the ground-tracks of the orbits over a given area for the whole duration of the mission it was possible to show that, in eight days—the normal duration for the first generation satellite—

[1] Perry, G. E., J. D. Slater, J. Marshall and S. Grahn, Spaceflight, London, *8*, 435, 1966.
[2] Perry, G. E., Flight International, London, *103*, 811, May 24, 1973.
[3] Perry, G. E., and J. D. Slater, Flight International, London, *86*, 842, November 12, 1964.

complete photographic coverage was obtained. The ground-track drifted slowly westward day-by-day until. on the eighth day it once again occupied the first-day's position.[4] There was also a correlation between launch-times and sunset-times in the northern hemisphere pointing to a desire to maintain some uniformity of lighting conditions.[5]

Complete photographic coverage for a non-manoeuvring mission is obtained with orbital periods given by

$$T=518{,}400n/(16n\pm1)\ (360.98+8.95\cos i)\ \text{minutes}$$

where n=length of mission in days; i=inclination of orbit to the Equator; and the sign is taken as − for orbits with a daily westward draft and + for those with i=81.3° which drift eastward.

This leads, in general, to greater orbital periods for flights at higher inclinations; for 12-day missions at 62.8° and 72.8° the periods evaluate as 89.23 and 89.58 minutes respectively. Reference to the complete table of launches in Appendix A to Volume 1 of this report will enable the reader to verify this for himself, even in the case of maneuverable payloads which could be expected to provide complete coverage if the maneuvering engine should fail in orbit.

The trend toward longer duration is a direct corollary of a general improvement in resolution. Obtaining better resolution on the same film format by use of longer focal length lenses results in a smaller ground area being photographed. The more closely spaced groundtracks and consequent lower period of the longer missions is obtained by lowering the apogee. Perigee heights have always been as low as practicable consistent with keeping air-drag to an acceptable minimum.

Examples of complete coverage for non-manoeuvring missions are given in Figs. 6A2–3(d) and 6A2–4 for Kosmos 599 and 759 in Section VI of this Annex.

IV. Radio Transmissions and Telemetry Formats

The first signals from one of these recoverable missions received in Kettering originated from Kosmos 13 early in 1963. It was immediately apparent that a type of modulation different from that previously encountered was being employed. Until then, all short-wave signals from the first Korabl Sputnik and the non-recoverable Kosmos 1 and 5 had been simple on-off keying of the carrier wave. The Kosmos 13 signals were frequency-shift keyed (f.s.k.) with the "off" periods being transmitted on the second frequency. The telemetry frame format was the same as that of Korabl Sputnik 1—a characteristic "purr" due to a synchronizing train of rapid pulses followed by 15 words, or bleeps, transmitted at a rate of approximately one word per second. Removal of one of the two frequencies by adjusting to zero-beat conditions revealed that these words were pulse-duration modulated (PDM), the length of each audible "bleep" being a measure of some parameter onboard the satellite.[6]

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[4] Perry, G. E., Spaceflight, London, *10,* 204–206, 1968.
[5] Perry, G. E., Ibid.
[6] Perry, G. E. and R. S. Flagg, Journal of the British Interplanetary Society, *23*, 451–464, 1970.

A more detailed investigation by Flagg of the Soyuz 3 telemetry showed that the on-off transitions of these words all fell in a null in the square-pulse train used to synchronize the ground decommutator with the onboard commutator. He also showed that the combined on-off time of each word was defined by 32 pulses, although only 29 pulses are transmitted, and suggested that the telemetered values were quantized in 32 permitted durations. It will be seen that the 32 or 2^5 permitted values can be represented by a 5-digit binary code for digital storage and computer analysis. It is possible that values are logarithmically amplified before quantization.

It was found that the first word of the frame following the synchronization pulses existed in several modes.[7] During the main part of the mission it took values of 23 or 9 which came to be referred to as mode 1 and mode 2. A third mode of value 16 was observed immediately prior to recovery. Later, a fourth mode of value 30 was discovered and it was established that the recovery modes 3 and 4 are associated with modes 2 and 1 respectively, the change occurring at the instant of recovery capsule separation from the instrument package. Words 7, 9, 12, 14 and 17 also change at this time.

These modes provided a means of classification into mode 1 only, mode 2 only and mode-changers—those for which word 1 was observed to change from mode 1 to mode 2 in mid-transmission. Mode 1 only has been used to classify low-resolution missions in Table 6–11 whereas mode 2 only and mode-changers are classified as high resolution. The change from mode 1 to mode 2 only occurred when the satellite had risen well above the horizon of a principal ground-station on Soviet territory, suggesting that the change was due to line-of-sight rapid play-back of stored intelligence on another frequency—VHF or UHF.

The introduction of the manoeuvring capability coincided with the appearance of a new type of transmission in the form of Morse code groups. Although this was first identified in Kettering during the flight of Kosmos 280 it would seem that signals were received from Kosmos 264 but ignored and logged as interference. As the number of such missions increased so our understanding of these transmissions grew. Twelve groups of three Morse code characters were transmitted repetitively at a rate well within the reading capability of a competent radio amateur. With one exception the groups were formed by characters chosen to give a total of seven pulses per group in a 2–3–2 configuration; for example, MWI—2 dashes, 1 dot and 2 dashes, 2 dots. The other group was formed by characters giving a total of seven pulses in a 3–1–3 configuration. It is assumed that this 3–1–3 group served as a reference denoting the first of 12 parameters. A typical sequence from Kosmos 280 is as follows:

STS MOM IDN NGM MGN MWI NUN MWM AUA MOM NOA NKI

Initial attempts to interpret these groups as binary code were not encouraging as changes in groups appeared to be random. Study of the seventh, however, which changed continually throughout a mission, showed that they were indeed binary code but the first digit rather

[7] Perry, G. E., Flight International, London, *95*, 844–845, May 22, 1969.

than the last took the value 2⁰—the digits were read in the reverse direction to that used conventionally. If a binary 0 was assigned to each dot and a binary 1 to each dash, the seventh word was found to increase steadily throughout the mission. This was 7-bit pulse code modulation (PCM).

The sixth group was invariably MWI at the beginning of a mission, changing to MRI at the same time as the manoeuvring engine was discarded and thus indicating the probability of recovery on the following day. The 14-day flight of Kosmos 399 was probably extended at the last minute since the change to MRI occurred as usual on the 12th day whereas recovery did not take place until two days later.

The steady change in value of word 7 in the PCM frame and of word 13 in the PDM frame showed the usage of some consumable. The choice between attitude stabilization gas and photographic film was resolved in favour of the latter when Kosmos 463 was observed to use up this consumable at twice the normal rate in its half-the-normal-duration mission at the time of the Bangladesh war.

Transmission frequencies for these types of telemetry were 19.994 MHz for PDM and 19.150 MHz for the PCM Morse code. At times when two satellites of the same kind were in orbit simultaneously it was observed that the transmission frequency of the first was changed to enable the second to operate on the main frequency. PDM's changed to 19.989 MHz and PCM's changed to 19.300 MHz. Word 14 of the PDM frame changed from a value of 23 to 16 at this time.[8] On occasions this in-flight frequency changing alerted us to the probability of an ensuing launch and in the cases of Kosmos 240 and 345 suggested that their launches had been unavoidably postponed for 24 hours.

A new feature of the PDM types appeared following the general increase in duration to 12 days. Sven Grahn discovered that these extended-duration types also transmitted broad-band VHF signals on frequencies close to 66 MHz. The change from 8 to 12 days duration was accompanied by a relocation of the very high value in the 15-word PDM telemetry frame from 11th to 7th position. It was later observed that certain flights did not have this very high value at all initially but, toward the end, word 7 assumed this very high value at the same time as additional pieces appeared in orbit. Mode 1 satellites can now be divided into two groups: those for which word 7 is very long throughout and those for which it lengthens near the end of the mission. It has been shown[9] that the latter category contains those for which the Soviet reports to the annual COSPAR meetings assign scientific missions. These are the 3rd Generation Low Resolution PDM-Science types shown in Table 6–11.

Yet another type of f.s.k. transmission was discovered during the flight of Kosmos 364. In this type there appears to be no telemetry and the 19.989 MHz transmissions must serve as a tracking beacon on each frequency alternately for approximately 0.75 seconds. Recently, Wakelin has pointed out that the total cycle period varies from satellite to satellite whilst remaining close to the general 1.5 second period. It may be that this will provide yet another means of classification but that remains to be established. This transmission is duplicated on 39.98 MHz but the two transmissions are commanded on separately. A more positive method of classification is by frequency. A special sub-set of these

[8] Perry, G. E. and S. Grahn, Spaceflight, London, *10*, 431, 1968.
[9] Perry, G. E. Spaceflight, London, *16*, 69, 1974.

satellites transmit on the 19.994 MHz of the PDM satellites and study of the orbital parameters shows that they do not manoeuvre. It appears that these are taking over the role of the PDM low-resolution non-science payloads, the last of which, Kosmos 751, was launched last July.

V. Recovery Beacons

Following the loss of the PDM transmission from Kosmos 114 as the instrument package burned up on reentry, Sven Grahn recorded a continuous sequence of Morse code TK groups on 19.995 MHz. At the time we attached little importance to this, doubtless because they had not been heard before due to cessation of monitoring following the loss of the PDM transmission. However, later in 1966, a similar transmission was recorded in Kettering following recovery of Kosmos 126 when the receiver was left switched on. This seemed too much of a coincidence and special attention was paid to recovery of Kosmos 127. TK's were recorded once again in Kettering.[10] As time went by it became clear that these signals originated from the recovery capsule and were intended to assist recovery teams in locating the payload. The mean interval between loss of the PDM transmission and the onset of TK's was 6.75± 0.5 minutes. The TK transmission begins at the instant the parachute is deployed. An abrupt decrease in strength some seven or eight minutes later indicates the time of touch-down. The length of time for which these TK's persist after this is a measure of the precision of the recovery. There have been occasions when the TK signals have ceased abruptly in less than seven minutes without a prior decrease in intensity which raise the possibility of mid-air recoveries.

Pen-recordings reveal that the dash of the T has twice the duration of the dash in the K. Nevertheless such signals have become known as TK's "within the trade". Horst Hewel, of West Berlin, pointed out that TK's were sometimes transmitted simultaneously on both 19.995 and 20.005 MHz.

As time went by other beacons were observed. TG's were transmitted on 20.005 MHz by mode 1 only satellites. TF's became the trademark of the 3rd Generation High Resolution 2-tone Manoeuvrable class with TL's transmitted by the special sub-set classified as 3rd Generation Low Resolution 2-tone Science in Table 6–11. The common factor of the "T" in all of these is justification for placing the T first in each pair—a happy initial choice.

TK's having a longer duration cycle than usual were observed in 1970 persisting for quite long periods on days when no Kosmos recoveries took place. It has been suggested that these originated from practice recoveries for the return capsule of Luna 16.[11] This might also explain the TK's received during the flight of Kosmos 301. It is now believed that these originated from tests for recovery of a lunar return capsule prior to the launch of Kosmos 305, a case of presumed failure of a lunar probe to leave Earth-orbit.

No explanation is offered for TV's which have been heard on occasions.

The reappearance of TK's with the recovery of Kosmos 774 after an interval of more than a year following the phasing-out of the Morse code types was unexpected.

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[10] Perry, G. E. and S. Grahn, Spaceflight, London, *10*, 142–143, 1968.
[11] Perry, G. E. Flight International, London, *100*, 31, July 1, 1971.

VI. Identification of Possible Targets

The first opportunity to identify the particular target for one of the recoverable photographic missions arose in 1968, just prior to the introduction of the manoeuvring capability. The 149 km perigee of Kosmos 246 was the lowest ever used in the program and was located near 20° N, northbound. The launch on October 7, only four days before the planned lift-off of Apollo 7, seemed timed to provide passes in the vicinity of Cape Canaveral around local noon. The ground-tracks of these passes are shown in Fig. 6A2–1. Due to the extremely low perigee, the orbital period decayed quite rapidly from 89.3 minutes at launch to below 89 minutes at recovery. This caused the spacing between corresponding ground-tracks on successive days to become closer as time went by. On October 11, Kosmos 246 flew by Cape Canaveral only 30 minutes after the Apollo 7 launch at 1100 EDT. It was recovered at the first opportunity on the following day after a flight of only five days. So confident were we of this early recovery that we were monitoring from 0500 GMT onward and, although no signals were received at Kettering, Grahn had the TK recovery beacon in Stockholm.

Figure 6A2–1.—Ground-tracks of Kosmos 246, from right to left, of revs. 3, 19, 35, 51 and 67 on October 7 through 11, 1968.

The value of the manoeuvring capability was demonstrated during the Indo-Pakistani war at the end of 1971.[12] Kosmos 463 was launched into an 89.3 minute orbit at 65° inclination from Tyuratam on December 6 and passed over East Pakistan (now Bangladesh) on the following day after 14 orbits at its perigee height of 205 km at 0638 GMT—for local Sun-time add six hours. Two orbits later, perigee was lowered to 188 km, reducing the orbital period to 89.0 minutes and causing the ground track to repeat itself on a daily basis. Such a ground-track which, in the case of reconnaissance missions, repeats itself after a further 16 orbits, may be said to be stabilized. Times of crossing East Pakistan on December 8 and 9 were 0622 and 0605 GMT respectively. In order to re-position the satellite for favorable recovery on December 11, apogee was raised after 48 orbits to produce an 89.3 minute period once again. The ground tracks are shown in Fig. 6A2–2(a). It

FIGURE 6A2–2(a).—Ground tracks of Kosmos 463, from right to left, of revs. 14, 30, 46, 62 and 78 on December 7 through 11, 1971.

is of interest that the Morse code telemetry revealed the use of consumables, presumably photographic film, at twice the normal rate for a 13-day mission.

Meanwhile, on December 10, Kosmos 464 had been launched into a

[12] Perry, G. E., Spaceflight, London, *14*, 350, September 1972.

90.3 minute orbit at 72.9 ° inclination from Plesetsk. This higher-than-usual period gave a westerly drift of ground-track of 5° per day bringing it over East Pakistan at 0510 GMT on December 13, after 44 orbits. The 213 km perigee was initially at 60° N but, two orbits later, a two-impulse manoeuvre lowered both apogee and perigee to produce an 89.0 minute period with a 182 km perigee at 20° N. The westerly daily drift was reduced to less than 1° per day permitting three further daylight passes over the area before recovery after 94 orbits on December 16. The ground-tracks are shown in Fig. 6A2–2(b).

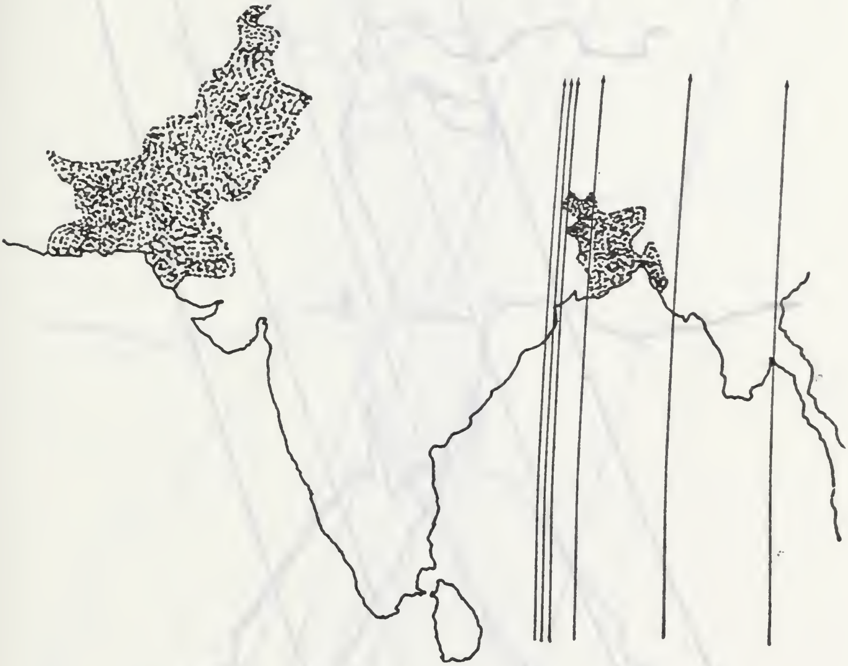

FIGURE 6A2–2(b).—Ground-tracks of Kosmos 464, from right to left, of revs. 12, 28, 44, 60, 76 and 92 on December 11 through 16, 1971.

The most intensive use of photographic reconnaissance satellites occurred during the Yom Kippur war in 1973.[13] When the war broke out on two fronts on October 6, Kosmos 596, launched from Plesetsk three days earlier, was already in orbit. However, this was a non-manoeuvrable, low-resolution type, providing only wide-area coverage. Within an hour of the outbreak of hostilities Kosmos 597 had been launched, again from Plesetsk. This was a high-resolution manoeuvrable satellite of the type which uses the two-tone short-wave tracking beacon.

On October 8, Kosmos 597 was suitably positioned to survey both

[13] Perry, G. E. Flight International, London, *105*, 240 and 245, February 21, 1974.

battle areas and its apogee was lowered to produce a stabilized ground-track with perigee over the Middle East on the northbound pass. By this time the orbit of Kosmos 596 had drifted westward so that it was no longer able to cover the situation and it was recovered after a flight of only six days. Its ground-tracks are shown in Fig. 6A2–3(a).

FIGURE 6A2–3(a).—Ground-tracks of Kosmos 596, from right to left, of revs. 14, 30, 46, 62 and 78 on October 4 through 8, 1973.

Kosmos 598, a "Morse code" type, was launched on the following day from Plesetsk into an orbit of inclination 72.9°. As can be seen from Fig. 6A2–3(b), the 65.4° inclination of Kosmos 597 provided passes over both the Suez front and the Golan Heights. By this time, the battle

for the Golan Heights was nearly at an end and the choice of the new inclination provided a photographic pass over the Middle East on the day after launch rather than on the third day of the flight. Kosmos 597 had been recovered after a six-day flight on October 12. Shortly

FIGURE 6A2–3(b).—Ground-tracks of Kosmos 597, from right to left, of revs. 14, 30, 46, 62 and 78 on October 7 through 11, 1973.

after this the apogee of Kosmos 598 was lowered to produce a ground-track with a slow eastward daily drift as shown in Fig. 6A2–3(c).

FIGURE 6A2–3(c).—Ground-tracks of Kosmos 598, from right to left of revs. 15, 79, 63, 47 and 31 on October 11 through 15, 1973.

It had become the established practice to produce stabilized ground-tracks by a two-impulse manoeuvre. The first burn would lower perigee to around 175 km to provide the optimum photographic coverage at the desired latitude on the northbound pass, and the second stabilized the ground-track by lowering apogee. The reason for the change in technique can be understood when it is realised that at a height of 210 km—a typical perigee for the initial orbit of these photographic reconnaissance flights—a satellite is just visible from a ground-station 14.5° due north of the sub-satellite point, whereas if the height is reduced to 175 km the ground range falls to 13.25° of latitude, a difference of 140 km. The ground-station at Yevpatoriya in the Crimea lies on approximately the same longitude as Suez and only 15.25° to the north, so the Russians had the capability of real-

time surveillance by sacrificing some degree of resolution which could be restored anyway by changing the focal length of the camera lenses.

The Middle East was not the primary target of Kosmos 599 which was launched from Tyuratam on October 15 with an inclination of 65.0°. It was a non-manoeuvrable PDM satellite which flew for 13 days instead of the usual 12 and provided photographic coverage of the battle area only on the last three days of its mission. This was probably a low-resolution flight, mounted to augment the results from the truncated Kosmos 596 mission. Its ground-tracks are shown in Fig. 6A2–3 (d).

FIGURE 6A2–3(d)—Ground-tracks of Kosmos 599, from right to left, of revs. 112, 128, 144, 160, 176, 192, 1 and 17 on October 15, 16 and 22 through 27, 1973.

Kosmos 598 was recovered on October 16 and immediately replaced by another "Morse code" satellite at the same inclination. This was the

first day since the outbreak of the war on which there was no photographic pass over the battle area. Kosmos 600 made its first pass on October 17 after 15 orbits. Its subsequent manoeuvres produced a unique pattern—an "Ali-shuffle" in space. Apogee was lowered on the second day causing the ground-track to drift slowly eastward, back across the battle area. Perigee was shifted to the southbound pass, preserving a 215 km height over the battle area, northbound. Two days later, apogee was raised causing the ground-track to drift westward over the battle area once again. These ground-tracks are shown in Fig. 6A2–3 (e). It was recovered on October 23 after a flight of seven days.

FIGURE 6A2–3(e)—Ground-tracks of Kosmos 600, from right to left, of revs. 15, 63, 79, 47, 95, and 31 on October 17 through 22, 1973

Meanwhile, on October 20, Kosmos 692 had been launched from Plesetsk. It was a manoeuvrable type with a two-tone short-wave tracking beacon. This time the ground track was stabilized with hardly any lateral drift. Fig. 6A2–3 (f) shows that this occurred when

FIGURE 6A2–3(f)—Ground-tracks of Kosmos 602, from right to left, of revs. 15, 31, 47, 63, 79, 95, 111 and 127 on October 21 through 28, 1973. The last four ground-tracks are practically coincident

the ground-track ran directly through the area of the Suez Canal. Kosmos 602 was recovered after a nine-day flight on October 29. During the later stages of the flight it was following Kosmos 599 over the battle area after an interval of some 70 minutes.

These stages coincided with moves in the United Nations Security Council calling for an immediate cease-fire, and although Kosmos

603 (launched on October 27) flew over the battle area on October 28 and 29, no steps were taken to stabilize the ground-track until November 1 when perigee was lowered in the usual pre-war manner to 175 km. Subsequently, full stabilization was achieved by lowering the apogee on November 5 after 142 orbits. Fig. 6A2–3 (g) shows that this

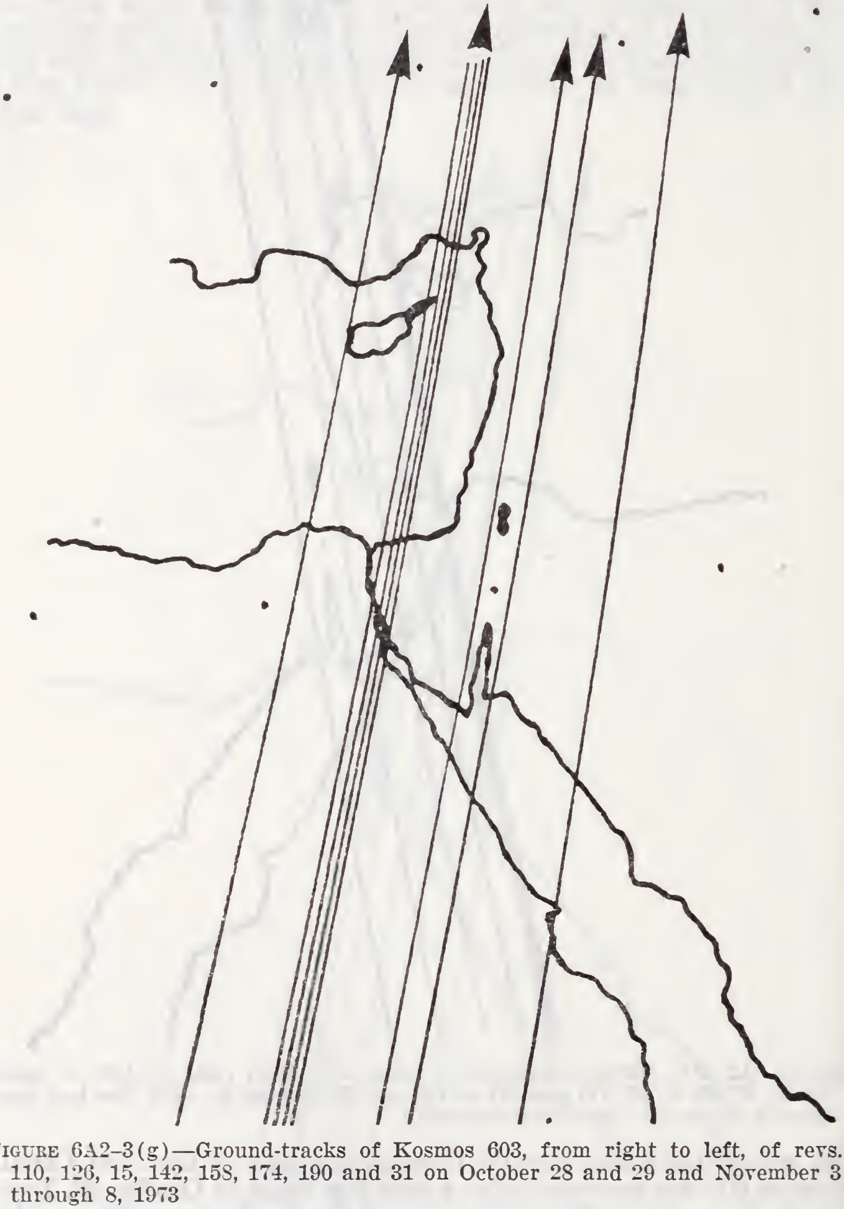

FIGURE 6A2–3(g)—Ground-tracks of Kosmos 603, from right to left, of revs. 110, 126, 15, 142, 158, 174, 190 and 31 on October 28 and 29 and November 3 through 8, 1973

was when the ground-track, once again, passed through the southern end of the Suez Canal zone. It was recovered on November 9 after the 13-day flight which was usual for "Morse code" satellites.

The six-point peace agreement between Egypt and Israel was signed on November 11. Kosmos 607 had been launched on the previous day and, like its successors, Kosmos 609, 612, 616 and 625, was doubtless used to monitor the effectiveness of the cease-fire.

The importance of the role of these reconnaissance missions was emphasized in a series of articles which appeared in the *London Sunday Telegraph*.[14] Under the sub-heading, "Cosmos knew better than Egypt," they wrote:

> Kosygin asked about the Israeli "incursion" and Sadat explained that it was a stunt to enable Mrs. Meir to cheer up her compatriots. But by way of the Cosmos satellite and Intelligence reports the Soviets were getting quite a different picture. The embassy received information and Cosmos pictures which were shown to President Sadat, and the Soviet military attaché spelled out for the Egyptians what it meant. Here were the Russians explaining in Cairo to the President of Egypt who did not know what was happening only a few miles away.
>
> The first concrete measure to help was ordered at once, and before Kosygin returned to Moscow, the Antonovs began flying in 300 Soviet military personnel.

In the three examples cited above the targets of the reconnaissance were fairly obvious but, in most cases, it is more difficult to determine the prime target, even if one exists. In the absence of manoeuvres to produce a stabilized ground-track the only real clue is to be found in the location of the perigee of the orbit. This defines a band of latitude close to which the particular target lies. Greater confidence is obtained if it can be shown that the time of pass through perigee takes place around local noon. If the ground-track is subsequently stabilized the analyst is then presented with sixteen fairly precise locations spaced at approximately 22.5° intervals around the latitude of perigee. A glance at a terrestrial globe will show that some of these may be eliminated as they fall over the oceans or, in the northern hemisphere, within the territory of the U.S.S.R.

The methodology can be outlined by consideration of a very recent flight with distinct peculiarities. Kosmos 759 was launched into a 62.8° inclination orbit from Plesetsk at around 0530 GMT on September 12, 1975. Although we had been expecting a launch following the recovery of Kosmos 757 on September 9, the launch took place 9.25 hours earlier than that of Kosmos 757 only sixteen days before.[15] Our mid-day monitoring session consequently failed to reveal the existence of the new satellite since it was no longer in range of the Soviet ground-stations at that time. We later learned that Wakelin picked up the two-tone short-wave beacon in Cyprus, at 0541 GMT shortly after insertion into orbit. Although TASS announced the launch at 1347 GMT it was not carried in the English news broadcasts from Radio Moscow that evening. I picked up strong two-tone signals on 19.994 MHz on my bed-side receiver at 0719 GMT on the Sunday morning at the start of the 35th orbit. This showed that it was a member of the special sub-set of non-manoeuvring payloads.

Aside from the unusual hour of launch, calculations based on two-line orbital elements issued by the Goddard Space Flight Center showed that the placing of perigee was also unusual in that, like that of Kosmos 720, it occurred close to 10° S on the southbound

[14] Dobson, C. and R. Payne, Why the Arabs didn't win. Sunday Telegraph, Lon [date ?].

[15] Recoveries normally take place in mid-week; in the last 18 months, almost two-thirds of the recoveries have been on Tuesday or Wednesdays. The implication of this is that, due to the standard 12 to 14-day durations of these missions, launches are made towards the end of the week. Aside from five Tuesday-launches, all launches of recoverable reconnaissance missions have been made on Wednesday (13), Thursday (7) and Friday (8).

pass. These two facts were shown to be interdependent when the time of passage through perigee was determined to be 1430 local Sun-time at the start of the mission, falling to 1100 on the day of recovery, for a given location. An inspection of an Atlas showed that only parts of South America, Africa, and northern Australia were situated at 10° S. However, on September 15, the London Daily Telegraph ran a piece on the withdrawal of the Royal Air Force from the Indian Ocean staging post of Gan in the Maldive Islands and referred to the U.S. Defense Department's proposed improvements to their base at Diego Garcia in the Chagos Archipelago. Here then was a potential target with the correct coordinates. Figure 6A2–4 shows the ground-tracks of Kosmos 759 across the area of the Indian Ocean. Whilst we cannot be sure that Diego Garcia was the prime target, since Angola and Timor also received a similar coverage, it will be seen that this satellite was well-positioned for photographic survey of Diego Garcia both at the beginning and end of its flight.

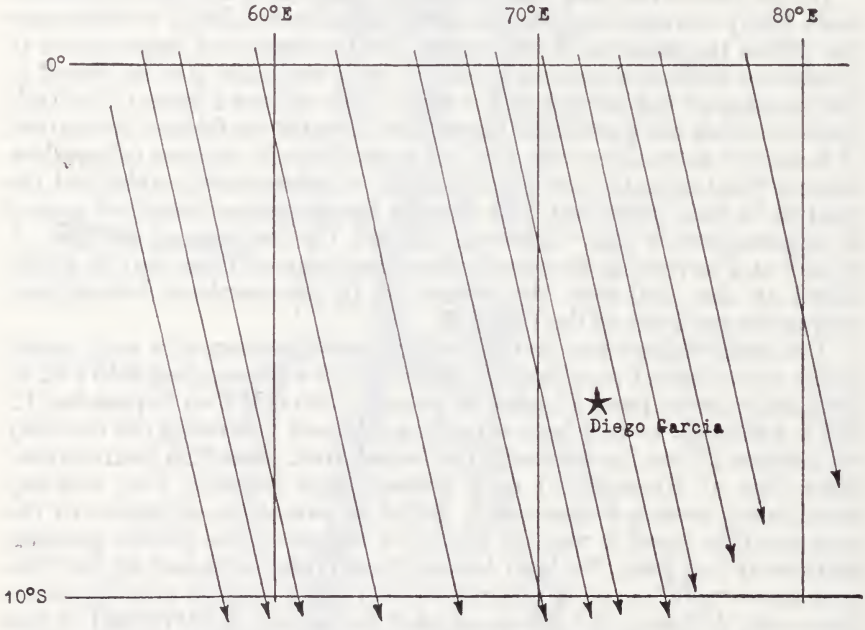

Fig. 6A2–4.—Ground-tracks of Kosmos 759, from right to left, of revs. 2, 18, 145, 34, 161, 50, 177, 66, 82, 98, 114, 3 and 130 on September 12 through 23, 1975.

Goddard Space Flight Center also revealed that three other pieces, perhaps fairings and protective covers for instrumentation, in addition to the final rocket stage were jettisoned after a few hours of the mission, and that two further pieces were discarded on the day of recovery. Recovery was also unusual in that the recovery zone was in darkness at the time. Wakelin lost signals after nine minutes at 2021 GMT on September 23, pointing to a landing at around 2035.

This account of the Kosmos 759 mission not only illustrates the methodology but also emphasises the dangers of being too dogmatic when drawing conclusions. The flight duplicated the flight of Kosmos 720 in earlier-than-usual launch time, recovery in darkness, perigee

height and location, radio signal-type, jettisoned pieces soon after launch and additional pieces (four in this case) on the day of recovery. It might well be that these two satellites had dual-purpose missions—military reconnaissance and Earth resources survey—and that the newspaper reference to Diego Garcia was purely coincidental and provided me with a convenient "red herring" . . . but then, that is all part of the fascination such a hobby provides!

VII. Related Observations of Telemetry for the Manned Programs

The vast size of the Soviet Union enabled a network of ground-stations to be established providing a good degree of coverage for low Earth-orbit flights but, from the earliest days, the Soviet Union has placed great reliance on the use of short-wave communications to compensate for the lack of ground stations outside the territory of the U.S.S.R. As time went by, ships of the U.S.S.R. Academy of Sciences were deployed to supplement the coverage from home-based stations but, even today, their manned spacecraft are out of range of direct communication for long periods.

The value of long-distance propagation of high frequency radio waves by "whispering gallery" modes within the ionosphere became apparent when the signals from the first Sputniks were received at times when the satellites were well below the horizon of the receiving station. Consequently all Soviet man-related flights have transmitted either telemetry, voice or both on frequencies close to 15, 18, or 20 MHz for at least part of the time.

The first Korabl Sputnik used a pulse-duration modulated (PDM), 15-word telemetry frame on 20.005 MHz in May 1960. The Vostoks and Voskhods transmitted keyed C/W (continuous wave) and voice on a variety of frequencies.

PDM (pulse duration modulation) telemetry from Kosmos 140, the second unmanned Soyuz precursor, was detected in 30-second bursts at 2-minute intervals at Aberystwyth and hindsight suggests that the intervening 90 seconds were occupied by a continuation of the transmission on each of three other frequencies. This provided valuable data on which to base the choice of frequency for the manned Soyuz missions to follow.

The only recording of transmissions from the ill-fated Soyuz 1, known to the Kettering Group, is on one of Flagg's tapes. Although unlogged, it comes between two identifiable recordings made on dates falling either side of the Soyuz 1 flight. This shows that the frame format was the same as for Kosmos 140 and all subsequent Soyuz flights.

Thirty-second bursts of this type of telemetry received in Kettering on October 27, 1967, indicated to Perry that Kosmos 186 (not announced until the afternoon following the Kettering disclosure) was the first unmanned test of Soyuz since the Komarov fatality.

The Soyuz 3 flight confirmed that the same telemetry format was still being used for the Soyuz program. Up to the launch of Soyuz 4, word 8 of the telemetry frame was always observed to be of medium length. However, when Soyuz 5 was launched on the following day, word 8 was seen to take one of three values which may be termed short, medium, and long. Since this was the first 3-man Soyuz, Perry realized

that this word related to the individual crew-members and went on to show that there was a regular sequence with each state held for one minute.[16] The fact that word 4 exhibited the same periodicity pointed to biomedical subcommutation with word 8 indicating the cosmonaut being monitored at the time and word 4 probably relating to respiration-rate. Supporting evidence for this was later obtained at intervals from TASS reports of values for such rates for different crew members. It was thus possible to assign the medium value to the commander in the center seat, the short value to the test-engineer in the left-hand seat and the long value to the flight-engineer seated on the right.

The Soyuz 4 and 5 mission also provided a clue to the function of the very short words 6 and 7. During the time of the EVA transfer of Khrunov and Yeliseyev from Soyuz 5 to Soyuz 4, word 7 became very long and this, together with subsequent observations that it also became very long immediately prior to the separation of modules for reentry, suggested that it was a measure of the degree of pressurization (in terms of vacuum) of the orbital module, which was serving as an airlock at this time. Word 6 was assumed to refer to the pressure in the reentry module. After the EVA transfer had been completed, word 8 of the Soyuz 4 telemetry frame took on the short-medium-long sequence whereas that of Soyuz 5 remained medium until recovery.[17]

Word 13 of the Soyuz 9 frame took a minimum value that sounded like a "blip". This was presumed to refer to the rendezvous system which was not carried on this solo flight—a fact confirmed by the Soyuz 9 commemorative stamp.

Such considerations of short-wave telemetry from Soyuz 11 showed nothing untoward up to the moment of separation of the modules immediately prior to reentry—the instant of tragedy.[18]

No obvious biomedical sub-commutation has been observed in Soyuz flights after this time but support for the hypothesis of pressurization information being carried on words 6 and 7 came during the Soyuz 16 flight. These words were both observed to lengthen during the 5th orbit but neither reached the very long state associated with complete depressurization. This suggested that pressure-dumping to the level planned for Apollo-Soyuz Test Project (ASTP) had been practised. This was confirmed during the ASTP mission and published data from that flight may be used to provide calibration for the telemetry.

The short words 6 and 7 are characteristic of Soyuz and observations in Kettering and Akrotiri showed that Kosmos 772, with the short words, was an unmanned test of Soyuz. In this instance, words 4, 12 and 13 were all blips.

The first Salyut transmitted C/W PDM telemetry, similar to that of Soyuz, on 15.008 MHz. Here the characteristic short words appeared at 3 and 7 in the frame. Toward the end of the manned phase of its operation it transmitted its own format on the Soyuz 11 frequency of 20.008 MHz.

The Kettering Group failed to pick up any signals from Salyut 2 but it is probable that it used the same 19.944 MHz frequency which

[16] Perry, G. E. and R. S. Flagg, Journal of the British Interplanetary Society, *23*, 451–464. (1970).
[17] Ibid., Fig. 7, p. 459.
[18] Perry, G. E. Northampton and County Independent, *60*, 24–25 (October 1971).

Grahn discovered was being used by Salyut 3. Some analysts even doubted that it was a Salyut intended to be visited by a human crew. This was followed by Kosmos 557 which appeared optically brighter, suggesting that it was larger. Its transmissions on 15.008 and 922.75 MHz made some people insist that it was only a Soyuz test rather than a Salyut station which failed early in its mission. However, the telemetry format with short words 3 and 7 was more akin to Salyut 1 than to Soyuz.[19] Positive confirmation of its Salyut relationship was provided by the telemetry on 15.008 MHz from Salyut 4 which differed only in respect of word 8.

Salyut 3 telemetry on 19.944 MHz was f.s.k. like the early recoverable Kosmos satellites instead of the C/W of the Soyuz and Salyut 1. Paul Rosser, a pupil at Kettering Grammar School has analysed 70 or so transmissions recorded at various stages of its mission. The lengths of words 1, 3, 4, 6, 14 and 15 remained more or less constant throughout the flight. So did word 5 at a half-length until January 5, 1975 when it began to decrease to a very low value by the time the flight ended on January 24. Some of the other words were more interesting. Word 2 showed a steady decrease in length whereas word 7 increased. Word 8 increased in length during the period in which the station was occupied by the Soyuz 14 cosmonauts and words 9 and 10 which were blips during the unmanned phases of the flight became three-valued when the crew was present. It is interesting to note that on the occasions when the cosmonauts returned briefly to the Soyuz, these words reverted to blips. A suggestion of an approximate 40-day periodicity in the length of word 11 might possibly be due to a variation of Sun-angle at the solar panels producing a corresponding variation in battery-charging current. Before the launch of Soyuz 14, word 13 was short but increased to a long state during the time in which the Soyuz 14 crew were in orbit. Immediately prior to the launch of Soyuz 15 it was back in the short state, lengthening once again during the two-day Soyuz 15 flight. However, it remained in the long state until a week after the capsule was returned to Earth in September 1974. Thereafter, it remained in the short state until the end of the flight.

Word 12 was always three-valued taking long, short and medium states reminiscent of the original Soyuz word 8. Perry was able to show that it was in the long state when he first received transmissions and that the change to the short state occurred very shortly after the spacecraft rose above the horizon of the Yevpatoriya tracking facility in the Crimea. After 7 or 8 frames in this state, corresponding to a total time of two minutes, it reverted to the medium state. The transition from medium to long was never observed at Kettering. Perry suggests that this word relates to the onboard tape recorder which is in the record-mode when represented by the long state. After rising above the horizon of the ground stations it plays-back on command, the data stored on the tape. Initially the play-back took two minutes but later in the flight this time became quite irregular. It is also suggested that the medium state indicates re-wind of the recorder.

David Dean, another of Perry's pupils, made a study of the broadband FM voice transmissions on 121.75, 142.4 and 143.625 MHz. In

[19] The Kettering Group, Spaceflight, London, *16*, 39–40, January 1974.

these, the cosmonauts have been heard reading through a series of numbers prefaced by the words "Form 2" and "Form 3". He has shown that the less frequent Form 2, containing fewer numbers, relates to the medical status of the crew and that Form 3 is concerned with the spacecraft's systems status. There have been indications when a specific time or orbit number has been quoted that the data refer to an earlier period when the spacecraft was out of communication with ground-stations. Dean has been able to correlate certain numbered data points with values for humidity (typically kept constant at around 10 percent), partial pressures of oxygen and carbon dioxide, total pressure and temperature. It appears that the latter are measured at two or three locations corresponding to the Soyuz orbital and reentry modules and the Salyut space station. Dean also has noted that the Soyuz 14 Form 3 contained far more data points than the corresponding forms for Soyuz 16, 17 and 18.

This observation of Dean's, the use of different frequencies and transmission mode and the all-military crew of Soyuz 14 points to the existence of two parallel space station programs within the Salyut label: one military in a low Earth orbit and the other scientific in a higher orbit. Perry has pointed out that no recoverable reconnaissance Kosmos payloads were flown between the recovery of Kosmos 674 on September 7 and the launch of Kosmos 685 on September 20 during which period the Salyut 3 station was passing over Kettering at times normal for the recoverable Kosmos types. Moreover, it was officially announced that a data capsule had been automatically returned to Earth on September 23.

CHAPTER SEVEN

PROJECTIONS OF SOVIET SPACE PLANS

By Charles S. Sheldon II*

I. Introduction

The preceding chapters have discussed Soviet space activities and programs for the years 1971 through 1975 inclusive in greatest detail, plus providing considerable historical material to summarize earlier flights and to complete time series in statistical tables. There have been some occasional references to trends and extrapolations which pointed toward the future. The purpose of this chapter is to deal more systematically with what the Soviet Union may do in the years ahead.

A. How Plans Can Change

No one has found a technique for reading the future, and this study will not be able to break new ground in this regard. What this chapter will do is identify and comment upon existing trends, assemble quotations on what the Russians themselves have said about their future activity in space, and provide some possible scenarios for implementing some of the projections.

Recent history seems to provide little confidence for assertions that some political systems are inherently more likely to follow a steadier course than others. There are differences of appearance and detail in the decision-making process in Western-style democracies and in more centralized societies where decisions seem to come from the top down. These differences in certainty of plans are so contradictory and kaleidoscopic, that almost any model explaining the differences can be challenged.

In the United States we make budget decisions each year for many programs and some people fear we can blow hot and cold so quickly that orderly progress is difficult. But we also use "no-year" funding for some projects and we increasingly supply at least five-year costouts on projects. Also other programs are funded on a mandatory basis, so that the amount of the Federal Budget which is truly controllable each year is so limited as to make freedom to be flexible not always easy. In our representative form of government, with checks and balances among the legislative, executive and judicial branches, the pattern suggests that major decisions usually require a fairly broad base of public support, and wild swings may be tempered by the almost cumbersome process of bringing together all interests that make inputs.

In the Soviet Union, it is possible that decisions from the top down on the one hand can change very quickly without a popular referen-

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dum, but also some decisions can continue for many years without the annual budget contests between a President and a Congress faced in the United States. But the political system of the Soviet Union as in all states must be responsive to some kind of a consensus if it is to survive for long.

In the United States, in spite of our slow processes where issues move through the bureaucracy and the Congress, and where many interest groups throughout our society make their inputs, we have had an example of a fairly sharp shift in attitudes. In the summer of 1969, Apollo 11 reached the surface of the Moon, a great euphoria swept the public, and many foreign nations also seemed not only to be impressed with the achievement but to share in the success. The Vice President called for going on with a manned expedition to Mars. But within a matter of months, it seemed as if the space program fell into some lower estate with much more attention focussed on ecology, pollution, and social changes. It was popular to label the space program as a misguided and not very useful effort. Actually, space expenditures had peaked in the middle 1960's and had been going downhill quite markedly since that time.

Although we can study Soviet decision-making from its outward manifestations, many of us have less of a feel for the subtleties of their processes. Over recent decades we have seen changes in Soviet political alignments. There was the Russo-German pact of 1939; then the U.S.S.R. was an ally of the Western democracies; post-war America became the prime "enemy" of the Soviet bloc; now we have détente and our men have flown together in space.

Probably careful analysis will show consistent threads of national interest prevail in both kinds of societies, but the current manifestations can seemingly change quite abruptly and even arbitrarily. The task here is to discern some of the underlying, persistent goals, but to recognize the sharp shifts of direction which may occur from year to year.

B. PAUCITY OF SOVIET INDICATORS

It is hard enough to predict trends in the U.S. space program when business cycles and popular enthusiasms of particular times shift the relative priority of work on space. Estimating Soviet behavior has added difficulties. They have never provided a table of space expenditures or budget commitments. Even if they did, there would be translational difficulties to understanding what they were doing when the costs of the factors of production in the two countries give entirely different ratios to the relative values of different inputs. In the absence of any economic measures, we have to fall back on counting the number of flights, estimating weight of hardware, and looking for clues to Soviet attitudes in speeches and articles.

To a considerable degree over the last 20 years, the two space programs, American and Soviet, have interacted politically with each other, regardless of disclaimers by leaders in the two countries. This interaction means that judgments of either program cannot be taken in isolation but must be tempered and modified by what each observes or assumes about the other nation. Hence, what the United States decides on the space shuttle, planetary flights. Earth resources satellites, and military applications could have significant repercussions in

Soviet planning as well. That is not to say reactions are one for one, merely that size and pace of programs and sometimes the choices to avoid direct overlap and sometimes deliberately to race to be first or to excel will all be possibilities. The repercussion will be there even if we cannot predict its nature.

C. EFFECTS OF PERSONALITIES AND SPORADIC EVENTS

Analysis would be manageable if all we had to worry about was a study of long-term national aspirations and economic conditions, together with the state of the art in technology. Human history is still affected by personalities and by natural calamities or other sporadic events that our present state of knowledge does not permit us to predict precisely.

The appearance of a particular personality may be partly a response to the times, but the sudden ouster of Premier Khrushchev or the assassination of President Kennedy could make a difference in support for a program. Most observers feel the death of Chief Designer Sergey Korolev made a real difference, a setback to the Soviet program. Certainly deaths of cosmonauts or astronauts in accidents bring investigations, delays for redesign, and more boldness to critics of a program. The failure of the Soviet G–1–e launch vehicle to achieve a successful flight in 1969 or during the six years thereafter must have affected the Soviet timetable if not the objectives of some parts of their space program.

D. CAPABILITIES VS. INTENTIONS

With all these caveats and examples of uncertainty, perhaps the proper mood has been set for examining the future of the Soviet space program. There is an analytical distinction in forecasting work which is common to military affairs and equally appropriate here. This is to recognize the difference between capabilities and intentions. A careful study of past performance, manpower, economic strength, production facilities, and other ingredients will answer reasonably well what a nation might be able to do. But no nation has the resources to pursue all of these capabilities simultaneously, and the more difficult task is to divine intentions. The verb "divine" is selected deliberately, because there is no real science to knowing what the future choices will be. As events come closer, there are indicators that give clearer and clearer warning. But longer range forecasts are harder. Also, in high technology some projects can be undertaken with several subsystems not yet in hand, but if good resources of brain power, laboratory facilities, and computers are applied, the capability will appear and grow, assuming what is sought is within the limits of the laws of nature.

Presumably if the Russians set their priorities high enough on a few projects, and apply their best talents to them, they should be capable of advancing as fast as any nation could hope to in these selected areas. Neither the Soviet Union nor the United States has the resources to pursue all avenues and all programs their engineers and scientists can propose in good faith. In a largely closed society in contrast with our own, it is sometimes hard to read intentions until a time almost too late to adjust one's own responses. The study of the Russians' own predictions of what they will do in space is interesting, sometimes helpful, and sometimes not very meaningful because no time scale is provided.

II. General Technical Capacity

A. OVERALL SUPPORT

1. Industrialization and Gross National Product

Judgments vary as to where the Soviet Union is in technology relative to the United States. Overall. as a less developed country it is not as advanced, and field by field, people close to that field are able to estimate "on a par or ahead", or "two years behind", or "six years behind", or "not in the running". An overall measure of comparison is the amount of Soviet gross national product, which is said to be about half as large in the aggregate as that of the United States. But the closer one comes to learning how such estimates are built, the more elusive the comparison becomes. Any two societies or even the same society in different decades have such changes and differences of product mixes that comparisons of GNP may be generally indicative but cannot be precise measures. Whenever U.S.-Soviet comparisons are made in ruble prices, the ratios are quite different from the comparison if made in dollar prices.

The industrial revolution began in Russia before World War I, but well after it was fairly advanced in Western Europe and the United States. Between World War I and World War II, the Russians paid a considerable price by collectivizing their farms and putting stress on heavy industry to the exclusion of many important aspects of balanced growth. Armaments have been a heavy drain, and the physical destruction of World War II was very great. Growth some years has been high compared with the United States because the base figure was so low, but the growth was not as great as that shown by postwar Germany and Japan, which also suffered heavy war damage. The phenomenon of slower growth rates now is almost worldwide. Today, while Soviet consumers are much better off than they have been in the past, the U.S.S.R. lags behind even some of the Soviet bloc countries of Eastern Europe, because of a continuing emphasis upon industrial growth and military hardware. The Soviet economy today is large enough and strong enough, despite shortages, that it can support what is now the world's largest space program, with no sign that this level of effort cannot be sustained indefinitely.

2. Key Industries

By selective application of the most efficient parts of their economic and technical structure, the Russians have been able to match the performance of other leading countries in selected fields, when they have chosen to do so. The general view has been that they are behind in electronics, microminiaturization, computers and some kinds of chemistry. All such comparisons are relative and subject to change. It is easier to point to specific examples than it is to quantify any overall comparisons. For example, although their electronics may not be the very best, some of their radars are rated as quite good. We know they do not have as many computers as the United States, and probably are not as advanced in the computers they have, but the kind of estimates one receives are that they may be about one generation behind, perhaps four or five years, while it was not so long ago they were two generations behind, the equivalent seven to nine years. While clerks in a store may use the abacus, computers in high priority uses are conducting

support for space rendezvous and missile intercepts, or supporting the Gosplan. Hence, even if it was judged that in many technical fields they were two to five years behind the United States, that would hardly be a basis for writing off their capacity for further progress, or for finding ways around some specific limitations.

3. Education and Manpower

The Soviet Union today has a larger student population in science and engineering than does the United States. While the two countries are more or less matched in numbers of working engineers and scientists, any extrapolation of trends based on the number being trained gives the Soviet Union a strong emerging lead. However, some studies suggest that much Soviet technical training is narrower, and in a time when many people end up having more than one career as national needs change, the American trained engineer may prove more adaptable collectively than the Soviet counterpart. At the top, the very best people in terms of performance, breadth of grasp, creativity, are about equal in both countries.

The Soviet Union is a nation with a large population, many technical institutes, a good base of trained manpower, and reasonably good access both to their own many scientific journals, and the shared world community of knowledge. If it chooses to pursue a large space program that is both vigorous and ambitious, it is in as good a fundamental position to achieve this as any nation.

B. SUPPORTING HARDWARE AND FACILITIES FOR SPACE

1. Launch Sites

The Soviet Union demonstrates from time to time that its three launch sites each of which is spread over many square kilometers of terrain and with multiple pads, are capable of conducting a considerable number of space launches in a few days. Their annual total launches are the highest in the world even though some pads and some vehicles are used only sporadically. Perhaps a contributing factor to high launch rates is the checkout for many vehicles done in horizontal assembly, followed by rail movement to the launch pad and a short time in vertical position on the pad before launch. This type of launch may be typical even of the D class launch vehicles, but less is known about the long-delayed and uncertain-performing G class vehicles which are so large that they may have to be assembled and tested on the pad.

2. Tracking Systems

The Soviet Union still lacks a deep-space worldwide network equivalent to that used by NASA, but manages passably by timing major activities to occur within view of Yevpatoriya in the Crimea. There may be another deep space capability in the Soviet Far East, but this cannot be confirmed. Additionally, their three largest tracking ships, while falling short of the high capacity of Yevpatoriya, can give important global coverage, especially up to lunar distances.

Soviet ability to do automatic rendezvous and docking, intercepts, and 24-hour synchronous flights suggests their general Earth orbital capacity is at least adequate. We also have seen them run the Soyuz 6, 7, and 8 operations simultaneously, and the Salyut 4, Soyuz 19, and

Apollo operations simultaneously. We also know that they have at least redundancy in control centers having these at Yevpatoriya and Kaliningrad as a minimum.

3. Manufacturing and Testing of Space Hardware

We do not know in detail what their full capabilities are in this regard. It has been believed in the past that ground test facilities were limited and many vehicles and payloads were tested in all-up flights with a consequent higher loss rate than would otherwise likely apply. Virtually all major flights now are described as being matched on the ground by an analog in a test chamber on which commands can be tested, and fixes in emergencies tried before commitment to the flight itself. There is probably some basis for belief the Russians do not have as much computer capacity dedicated to checkout and testing as do their American counterparts.

Because the continuing Soviet flight program itself is so massive year after year—three times that of the United States—there seems little challenge to the notion they can sustain the present high level of activity indefinitely. At least until the American shuttle becomes operational, a continuation of these trends would guarantee Soviet leadership in space over a period of time. If the Soviet economy continues to grow, and this program holds a proportionate share, then we may see an even larger Soviet space program, although not one growing as fast as it did in the 1960's. Soviet capabilities will be enhanced as their computer capacity grows and as they apply more attention to cybernetics, to quality control, and to advanced industrial management and operation.

C. VEHICLE CAPABILITIES

1. Existing Vehicles

The spectrum of existing vehicles is adequate to take care of a fairly comprehensive space program. Although the A class of vehicles, in use since 1957, may eventually be declared obsolete, there is no real sign of its replacement. Through upgrading of payload capabilities, some tasks previously handled by the C class vehicles are now being handled by the larger A class. An even larger number of payloads once handled by the low capacity B class vehicles now are routinely handled by the more powerful and more versatile C class.

The D class launch vehicles are gradually becoming more reliable, even though not yet proven as man-rated in the launch phase. At the least, this delay in man-rating cost the Russians the first successful manned circumlunar flight, as well as causing many grievous losses of expensive payloads to the Moon and planets.

The use of F class launch vehicles for military missions has not accelerated yet despite the apparent simplicity of the basic design concept and the maneuvering capabilities which have been demonstrated by upper stages.

The G class vehicles remain the biggest unknown because there is so little information in the public domain. Soon it will be a decade since their first use was expected, which is why some observers think they never existed and others think they have been written off. It seems both not consistent with the kind of testimony from high level U.S. officials, and not in keeping with Russian determination to be a space leader to accept either of these viewpoints. Although a decision to abandon could

still come, the best guess now is that one of these days, we shall see a successful flight of a very large vehicle. After the troubles it has already experienced, one can imagine a possible redesign effort and also major steps to increase testing, reliability, and simplified operations to insure that so expensive a vehicle will do what is intended of it.

2. Additions to the Vehicle Stable

Studies by Western observers have suggested that in many instances there is a product improvement trend in Soviet launch vehicles which allows the upgrading of their capabilities over a period of time. But perhaps some existing models can be pushed only so far at reasonable cost and risk. Hence, some Western observers postulate that we shall see new additions to the known types. For example, many of the Western analyses of expected Soviet missions suggest that the D class vehicle is not quite equal to some useful missions, and a vehicle larger than D but not as large as G would be a useful gap filler both in Earth orbit and in deep space work. Until such a vehicle appears or its facilities are evident, considering the Soviet penchant for secrecy, it remains highly speculative to assume its certainty.

3. Use of High Energy Fuel in Rockets

The Russians have not been in any hurry to move to high energy fuels as we understand them, because they had the early advantage of bigger capacity in their conventional rockets. Also, high chamber pressures were fairly typical so that they got quite a bit of performance from these engines. It is really a surprise that a decade behind the Americans, we have not had any good indication of Soviet operational use of hydrogen-oxygen combinations. In general, they are content to cluster large numbers of engines of moderate size as they need more thrust. Perhaps since they have not taken the fairly obvious and clean route to use of hydrogen and oxygen, it is even less likely that we shall see early Soviet use of hydrogen-fluorine, metallic fuels, or other exotic and toxic types.

4. Nuclear and Electric Rockets

There is no good evidence in the public domain to answer how vigorously the Russians are pursuing development of solid-core nuclear fission rockets, even though they are well aware of the possibilities and of previous U.S. efforts in this regard. One can assume that at least paper studies and breadboard engines have been tested, as in keeping with Soviet status as a leading space power. Soviet spokesmen of the caliber of Glushko have stressed the important place nuclear power can hold.

Electric rockets have a potential both for station-keeping and for gradual acceleration on very long flights. Here there is more evidence that Soviet work continues actively in flight tests. Preceding chapters have given examples of several classes of flights which have included electric rocket systems. Those relying on solar cells provide measurable changes of orbit, but not very large increments of velocity. Future systems may do more, though to date the only nuclear power sources announced or circumstantially suspected have been radioisotope thermal generators (RTG's), applying the heat from radioisotopic decay and not chain reactors of the full-scale fission type.

5. Reusable Vehicles

The United States space program leaders have recognized the development of a reusable space shuttle as a key step in putting the program on a long-term sustainable basis, pointing to the wastefulness of throwing away expensive hardware after brief use, and to the importance of providing a more benign environment to payloads so that design constraints could be eased, thereby cutting costs.

Soviet space spokesmen have recognized the same logic and see reusability as the only way to go. Soviet incentives may be even greater because their level of activity is so much higher that the overhead costs of developing such a system would be sooner recovered.

The press has been filled with rumors of such a Soviet development for several years, but there is no evidence in actual flights to give substance to the reports. That is not to say they are untrue, because it could be quite late in the development process before there would be overt signs of such a new system.

One of the most specific current stories on Soviet plans is that carried in June, 1975 by *Flug Revue und Flugwelt*, crediting A. Chikarin of the U.S.S.R. State Research Institute for Civil Aviation. The supposed system would include two completely reusable stages of delta wing platform, with the first stage flying to 2.2 km per second, and releasing at 30 km altitude an upper stage which would then accelerate to 7.9 km per second, Earth orbital speed. During reentry, in order to dissipate heat, the return glide would take about one hour instead of the ten minutes typical of ballistic reentries. The principal suspicion about the report is that the U.S.S.R. does not normally admit to new technological developments, especially to give details before they begin flying.[1]

III. A Chronology of Soviet Statements on Future Space Plans

This section discusses a moderately complete review of available actual quotations and paraphrasings of Soviet expressions on their future plans, goals, and policies carried as an annex to this chapter. By selection, one could bias an account to emphasize some preconceived notions of Soviet future objectives in space. Also, it would be easy to read more into these statements than in fact is there. Aware of these risks, the attempt has been made to include what could be found even when contradictory, and to let the statements or abstracts speak for themselves, with analysis to follow later.

The Soviet spokesmen, if known, are identified by names and categorized by occupations or position titles to the extent this can be determined. The published source of the quotation or reference is usually identifiable. If, in a few cases, lack of permission to quote limited full use of an item, a generalized paraphrase and reference to "news despatches" has been made. All TASS bulletins referenced are from Moscow unless otherwise indicated.

In the previous study prepared for the Senate covering the years 1966 through 1970, there was a similar chronology, and many of those items are still of interest. The annex to this chapter picks up a similar

[1] Hofstatter, Rudolf, In Flug Revue und Flugwelt, No. 6, 1975, pp. 107–108.

listing in December 1970 and carries it through 1975, to the extent material became available.

The material is in chronological order of publication, grouped by years. Cosmonauts are frequently making forecasts, and one does not know to what extent they are privy to official timetables or when their own enthusiasms run ahead of reality. Most of the academicians who speak also head important bureaus within the space program so that their views reflect greater program responsibility than might be true of American professors on the fringes of our actual operations. In a few cases, important officials are labeled in pictures and write for journals under pseudonyms. (Maarten Houtman of the Netherlands has catalogued the names of about 6,000 space technicians and officials, and the true names of about 60 known by their pseudonyms. He has found what patterns are applied to selecting pseudonyms.) For example, Valentin P. Glushko, the Chief Rocket Engine Designer, wrote in the open as Georgiy V. Petrovich, and only recently has come into the open.

It must also be remembered that some predictions which appear at more than one place in the chronology may have added weight for appearing several times, or it may be no more than a reflection that a one-time statement is reissued in a variety of publications in the absence of anything new to add.

The chronology referenced for the 1971–1975 period, as noted, is carried as an annex following this chapter.

IV. Analysis of Soviet Intentions in Space

A. UNMANNED SPACE FLIGHT

1. Earth Orbital Science

One of the more complete recent forecasts by a Westerner of possible Soviet plans is that written by Saunders Kramer, published in July 1975.[2] Kramer has done a thoughtful, integrated piece, but suffers the same disadvantage everyone does, that it is easier to calculate projections of capabilities than it is to know intentions.

Kramer has not said very much about Earth orbital unmanned scientific flights. A review of the statistical tables in this study will show that the Soviet Earth orbital record of science flights is a modest component in their total program; however, they apparently fly more such payloads these years than NASA does. There is some question whether they gain as much new scientific knowledge from each flight. The volume of published findings is considerable, but apparently computation is slow, and results are still being published on flights dating back even a decade and more. Many of the findings these days represent refinement of esoteric minutiae that are not very exciting to laymen, but presumably strengthen the foundation of understanding of phenomena related to particles, radiation, fields, solar processes, signal propagation, weather movements, climate, geomorphology, and so forth.

Some Western scientists talk down many of the Soviet experiments, and it is hard to know how much of that is the scathing review many

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[2] Kramer, Saunders B. Soviet space activity: The next ten years, Spaceflight, London, July 1975, pp. 242–251.

scientists give to each other's work, and how much is a matter of "not invented here" criticisms of other people's approaches. It is unlikely that the assessments are seriously tinged by differences of ideology as many scientists have a certain impatience with or indifference to political problems.

For the first ten years of the space program, only NASA had an extensive international cooperative effort underway. Today, the Soviet Interkosmos effort, plus bilateral work with France, the United States, India and Sweden give them a pattern not essentially different from that which NASA pioneered.

It can be expected that this program of unmanned Earth orbital science will continue at about the present level, done with fairly modest vehicles, and done with either international cooperation in preparation of experiments and readout of telemetry, or with fairly complete reporting of results at COSPAR meetings and in the open literature.

There may be some shift toward increasing use of manned stations of the Salyut type as affording better opportunities to gather synoptic data, with men to calibrate the instruments and make adjustments, rather than relying so extensively on unmanned vehicles.

2. Civil Space Applications

This study has shown that the Soviet Union has turned to applications flights at a later date than did the United States. But their present concepts for applications are fairly ambitious and moving ahead reasonably consistently, with quite large deployed patterns of spacecraft and more ambitious types in development.

a. Communications.—In the Molniya series, they are simultaneously using Molniya 1, 2, and 3 classes, with a pattern in each, of flights in planes 90 degrees apart. Experimentally, they have a Molniya 1 in 24-hour synchronous orbit, supplementing the 12-hour repeating ground trace flights in eccentric orbits that are operational together with the first operational 24-hour Statsionar. They have promised us further Statsionar flights in 1976 which will give them fixed antenna pointing, round-the-clock coverage for middle, southern latitude, and international service, to supplement the northern latitude including arctic coverage which the operational Molniya flights provide. The Statsionars are expected to come closer and closer to attaining a direct broadcast capability. The Molniyas already have supplied the first comprehensive domestic distribution system of any country.

b. Weather.—The Meteor weather satellites have evolved with the addition of more sensors, although basically they supply primary cloud cover pictures in the visual range by day and do infrared at night. APT (automatic picture transmission) gives real time coverage to users anywhere. The Meteor 1 class has been joined by the first of the Meteor 2, and perhaps this will expand into a whole new series. There is already a commitment to put up a 24-hour synchronous satellite south of Eurasia as part of the global system shared by Japan, Western Europe, and the United States. Again, these unmanned systems are likely to be supplemented by some manned coverage which on some orbits can watch particular weather phenomena.

c. Earth Resources.—Unmanned Earth resources survey work has been slow to mature to an operational system in the unmanned mode. There has been greater use of Soyuz and Salyut flights for such pur-

poses. However, valuable data have been supplied by Kosmos 243 and its successors with such devices as passive microwave and work in the ultraviolet range for data on temperature, humidity, soil conditions, and other phenomena. Even Soviet weather satellites, which have a fairly high resolution, have returned geomorphological details which have been used to locate oil fields and other mineral deposits. Color photographs taken from the circumlunar Zond craft covering much of Africa have provided geobiological maps which from single pictures have equaled the work of months or years on flights by aircraft closer to the ground, in classifying vegetation.

Some people have suggested that Soviet computer capacity is not yet equal to handling the great volume of data an Earth resources satellite is capable of returning, and that this is why we have not seen a full-scale operational deployment of such flights, even though the satellite sensors themselves are sufficiently developed.

d. Other.—It is assumed that Soviet navigation satellites are still largely dedicated to military uses, so that it is not known how soon or how far civil applications will be carried near term. The same is true of geodesy, mapping, and general data relay. Until these uses move out of the exclusively military sphere, it is difficult to make judgments about future civil use. Still newer activities like traffic control are yet to come.

3. Military Applications

Here again, the difference between capabilities and intentions is crucial. We can count on existing programs continuing and gaining in effectiveness. So long as this is all they do, the equations of power will not be seriously perturbed.

a. Recoverable Observation.—Many generations of these flights have come, as they enjoy a high priority and presumably are being improved. Such flights can be expected to give close attention to both area searches and close inspection, with larger numbers put up in times of crisis, and with some of them maneuvered to give more frequent coverage of order of battle data. Already there is circumstantial evidence that they are learning the techniques of returning data capsules, as done with Salyut 3 and as beacon signals suggest with some other flights. Presumably resolutions will improve as they perfect the various things which now limit them. They can fly lower, and use extra propulsion to prevent early decay. They may learn camera and film handling techniques to reduce the blur in pictures. The principal competitor to these automated flights is likely to be manned military space stations, although there are indications that a fourth generation of unmanned flight of longer duration is about to be introduced.

b. Early Warning.—Already there are flights which move in orbits like those of the Molniyas and which may give early warning. It is possible that 24-hour synchronous satellites for early warning will be deployed to give continuous surveillance that now is only periodic with the present 12-hour system.

c. Electronic Ferret.—These flights are used so extensively and have been available for so many years, that one assumes the principal change will be one of greater versatility and sensitivity in collecting data for analysis. There may be an upgrading to larger payloads as part of this improvement.

d. Ocean Surveillance.—The system is likely to move from early operational to full scale global coverage. Not only must radars be able to distinguish classes of ships, but the system will not be really operational until a big computer complex can keep track of all ships and is fed other data on ship movements and behavior before it will fulfill its potential.

e. Navigation.—There have been several generations of these flights already, and further improvements in accuracy can be expected, which in turn will open up applications of these techniques beyond location of nuclear submarines carrying ballistic missiles to all classes of ships and to tactical targeting for all military forces.

f. Geodesy.—Geodetic work is probably far enough along already to provide the Russians with reasonable assurance they have defined the geoid to the point that long range missiles will reach their targets if the rockets perform properly. As geodetic work continues, presumably the military uses will begin to gain a lower increment of new information than will the scientific uses of geodesy.

g. Mapping.—Mapping has always been important to military operations as well as to economic and scientific users. Probably mapping is already underway within the military observation program. What one might expect to see are flights more carefully placed at optimum, circularized orbits, and probably still using photographic film which can be recovered. Better selection of orbits would minimize the work of picture rectification required when many scales and many angles are involved. The work of map improvement is never ending because both natural features and man-made features are constantly changing the surface of the Earth, and getting really good stereo pairs of every part of Earth without cloud cover, and possibly doing so in several parts of the electromagnetic spectrum takes time.

h. Communications.—It would be strange if the Molniya satellites were not carrying military traffic, and the same can be expected of the Statsionar 24-hour synchronous satellites as they are put in service. There also may be a continuing need for the lower orbit store-dump type satellites because those which are put up eight at a time make up such an extensive grid that they provide some important redundancy against countermeasures. They may permit sure delivery of essential messages worldwide when real-time is not necessary, or they may supply a real-time capability to tactical forces in a given operating area even remote from home territories. The larger, more complex store-dump payloads may provide facilities for storing more messages, or for greater range of frequencies, so that it might be harder for other nations attempting to listen in to catch particular messages if these not only are encrypted, but may be sent line-of-sight in short, high-speed transmissions on any one of a number of different frequencies. Presumably this is a need which may continue for the Soviet Union.

i. Minor Military.—Earlier in this study, some flights were classified as "minor military" because they seemed to be repetitive payloads, largely put up by the B–1 vehicle, hence relatively small, whose purpose seemed obscure. It was speculated these could be doing ferreting, or radar calibration, or testing various sensors, materials, components, etc. These missions would seem in any case to be fulfilling

continuing needs, and such flights can be expected to continue, although it appears that the lower orbit missions are being phased out.

j. More Threatening Missions.—While all the foregoing make military contributions, they are essentially support, passive, and probably not necessarily destabilizing to the world scene. They increase the effectiveness of conventional air, sea, and land forces, and even of missile forces. Where they collect information, they may be creating de facto the kind of "open skies" situation which many arms control agencies believe is important to attaining workable arms limitation situations.

But what of other, potentially destabilizing missions in space? One such is the renewal of satellite inspector/destructor flights like those which ended in 1971. Inspection seems harmless enough, but the problem is that if satellites conducting military functions coorbit with uncooperative targets of investigation, the added capability of destruction is a very simple step compared with the rendezvous and the selection of sensors capable of doing a good inspection. Any space power must worry about the possibility that another space power may decide to escalate rivalries to the point of interference with satellites in orbit, whether it is to blind the eyes of some, or deafen the ears, or disrupt communications, or take away some abilities to navigate. This means that such nations must consider a range of both passive and active countermeasures available on a contingency basis. Presumably arms controllers will press for agreements to avoid mutual interference, while responsible military authorities will feel it necessary to have contingency plans in case the agreements are abrogated. Passive measures may include steps to make radar and visual detection more difficult, or possibly to have so many decoys that the expense of interception would be very heavy for the returns; also, there might be increasing use of signals buried in "noise" so they were harder to intercept, and more of them might be highly directional further adding to the difficulty of finding them. For the longer run, some types of payloads may be placed at greater distances from Earth.

Such protective measures may be used by the Russians against any perceived threat from the United States. Likewise, U.S. authorities, having seen a demonstrated Soviet capability to carry out inspection/destruction flights against targets at a number of altitudes have to assume that over a period of time the Soviet capability in this regard will grow. Meanwhile, it is apparently to the clear advantage of both nations to avoid direct interference with the space flights of the other, lest the price to be paid become too high and escalate events to very unpleasant and unforeseeable conditions.

In the area of weapons of mass destruction, deployment is prohibited by treaty. One may hope that such treaties will be honored indefinitely, and in this regard, fractional orbit bombardment system (FOBS) flights, which bordered on the questionable side, have not been flown by the Russians since 1971. Let it be clear that this paper does not recommend or even predict the abandonment of restrictions on putting weapons of mass destruction into space. Intellectually, it still can be recognized that in some future age if military rivalries of national states continue, and if major arms are not limited and controlled, one can imagine situations in which arms in space might be

a lesser evil. Just as today, moving the nuclear deterrent forces to sea in submarines has been seen as a way to avoid the temptation of a preemptive strike against land targets, one could argue that someday a deterrent based in deep space, say at distances farther away than the Moon and even on the far side of the Sun, might supply a believable, survivable deterrent that would have to be overcome before major powers could risk wholesale warfare closer to home. The notion of the bloodless war fought by computer-controlled automatons, machine against machine, is probably wishful thinking, but in another century might become a part of the institution of war.

Soviet military planners would be unimaginative if they did not think of the whole realm of possibilities and the military consequences as well as the scientific and economic advantages which may flow from future breakthroughs in space propulsion, power, navigation, and life support systems. Western analysts face the same needs if they are to have countermeasures and if they are to know what advice to give in future arms control discussions.

4. Lunar Studies

The full capability of the present series of unmanned lunar flights has not been exhausted. We can expect to see one or two flights a year, including the use of more sample retrievers, roving Lunokhods, and orbiters doing picture taking and more general studies. This will lead gradually to a more detailed mapping of the Moon and understanding of its morphology and history. If the Soviet prediction of combining a roving vehicle with a sample returner is to be executed, and if they continue to use the D class of the vehicle, there will have to be surface rendezvous of two payloads to carry this out. If they are to explore the back side of the Moon in similar fashion, it may require at least three vehicles, in order to deploy some kind of an orbital communications relay system before they can guide on the surface and get the right trans-Earth injection again while vital steps are carried out on the far side of the Moon. If the G class vehicle comes into use, more ambitious undertakings might be considered. At some point Soviet lunar exploration can be expected to shift back into the manned mode, to be discussed later in this chapter.

5. Planetary Studies

Both Mars and Venus flights have graduated to use of D class launch vehicles. These have greatly enhanced capabilities over what was done with earlier A class launch vehicles. But even for a Mars flight, the D class has proven to be so marginal that the 1975 launch window had to be skipped, and this was even after use of double pairs for the 1973 orbiter and lander missions.

Inherently, the D class vehicle is capable of lifting payloads in the American Viking category, and hence with the previous record of heavy Soviet commitment to planetary flight, there is reason to expect that the D vehicles for much of the next decade are likely to use most opportunities to fly to Mars and to Venus.

The Russians have talked about Lunokhod being a precursor for similar roving vehicles on the surface of Mars, and they have also talked of the importance of returning samples from other planets. It must be recognized that both tasks will be considerably harder than doing such work in connection with the Moon. The D class vehicles

might marginally support a small rover on Mars, but the rover itself would need a new degree of automation because any human operator would be too far away in time for round trip signals to guide such a vehicle under all circumstances. Perhaps even without full automation such a device might send back some pictures of the immediate topography in its path, then receive the command to move forward within first picture range, stop again to take a new incremental forward look, and after Earth consideration move forward again, without too much risk of driving up against a boulder or tackling too steep a slope. Returning a sample would require overcoming a greater gravity barrier than on the Moon, plus accelerating to a speed to permit return to Earth, with more complex fine tuning of the return path, and severe energy constraints on the times missions could be performed still to get back to Earth.

If the Russians during the decade upgrade their planetary efforts to use of the G class launch vehicle, then there would be a capacity to make unmanned round trips to planets and to put more ambitious experiments on the surface of planets. Venus on the surface is not very promising for longer duration experiments because of the high heat. But experiments which might float in the dense atmosphere but in a lower temperature range might endure for considerable periods. Mars does not seem to present as great obstacles to longer term study as the surface of Venus, unless the phenomena of large dust storms turn out to be a problem.

To date, the Russians have only talked about missions elsewhere in the solar system, and not conducted flights equivalent to the U.S. flights to Mercury, Jupiter, and Saturn. The D class vehicles are capable of supporting Mercury exploration, and while a more energetic final stage might be required, the basic lifting capacity of these vehicles also would support flights to Jupiter and beyond. Should the G class vehicles become available for a "grand tour" type mission with suitable final staging, then the kinds of missions for the late 1970's once talked about for Saturn V in the United States would be possible, with visits to a number of the outer planets over a period of years. At the moment it seems unlikely the G vehicles will be ready for such use in this decade, or that the priorities would accord it such assignment considering all the other reliability uncertainties in such a flight.

There are other missions which the Russians have acknowledged as being of potential interest. These include a flight out of the plane of the ecliptic by first making an approach to Jupiter; a flight to a comet; and a flight to a planetoid, or a landing on the satellite of another planet such as Phobos, Deimos, or a Jovian moon.

An extrapolation of past levels of Soviet planetary activity suggests that over the next decade or two, there will be fresh important Soviet advances in the planetary field. After a disheartening record of failures, they have persevered, and many of the flights are now successful, so that their existing commitment of resources even without a larger effort may be matched by a growing return of useful results.

B. MANNED SPACE FLIGHT

1. Soyuz

By now, Soyuz has evolved into several types of craft to fill several different needs. It may be useful to examine some of these categories.

a. Ferry.—There is a ferry version without solar panels and with modest maneuvering capability which can serve to resupply Salyut space stations. Relying on chemical batteries, it can operate independently for about three days, but attached to a Salyut, may lie dormant for up to 90 days, until it is needed for return to Earth.

b. Independent Mission.—A second version of Soyuz has solar panels, and can conduct experiments and tests that either are not suitable for a Salyut, or can be done when a Salyut is not available. The flight of Soyuz 13 was of this type, and the specialized ASTP Soyuz 19 was also in this category.

c. Component.—It is less certain what the exact role of Soyuz may be as a component in other, more complex missions. For example, the Zond circumlunar flights may have stood alone as modified Soyuz, or they may have been building toward more advanced missions involving the Moon. Another obscure example relates to Kosmos 379, 382, 398, and 434. These may have been testing parts of Soyuz, or may have used other man-related but different hardware. Kosmos 159 may also have tested some Soyuz component.

d. Docking Modes.—There may have been as many as five different types: active docking with probe; passive docking with receptacle; active docking with probe, plus hatch; active/passive with androgynous connection and hatch; no docking gear.

e. Tankage.—The first nine Soyuz carried a torus tank which may have been jettisonable, and in any case, the Zond payloads and the later Soyuz do not have this fuel tank.

f. Solar Panels.—Not only do the ferry craft lack solar panels, but those with panels have two types. The Zond and ASTP Soyuz 19 have shorter panels with three segments each. The Soyuz at least up through 11 have four segments to these solar panels. A few cannot be classified in the absence of pictures.

g. Work Module.—All regular Soyuz carry a work compartment, while the Zond variant did not.

h. Heat Shield.—The heat shield is detachable, and is dropped after reentry and presumably at about the time the parachute is deployed. It is possible that the Zond variant uses a heavier heat shield to cope with the higher reentry velocity.

i. Seats.—Presumably originally the regular Soyuz all had three seats, while the Zond may have carried only one seat. From Soyuz 12 on, all Soyuz have carried two seats, in order to carry men wearing space suits instead of coveralls.

All of these variations are important to understanding what Soyuz may have been intended to do and what it may be able to do in the future. Also there may be clues as to whether the ship was designed from the outset to perform many different missions or whether these evolved out of experience and necessity. Analysis of the possibilities by Westerners is closely intertwined with interpretations about Soviet intentions for other missions and spacecraft which will be turned to in the pages ahead. This makes any discussion somewhat complex and overlapping. See Table 7–1 for a summary of suspected differences among Soyuz-related spacecraft.

TABLE 7-1.—LIST OF SOYUZ VARIANTS

Flight name	Launch vehicle	Service module	Solar panels	Torus tank	Command module	Work module	Docking gear
Proton 1	D-1?	mock-up	special	n.a	n.a	n.a	n.a.
Proton 2	D-1?	mock-up	special	n.a	n.a	n.a	n.a.
Proton 3	D-1?	mock-up	special	n.a	n.a	n.a	n.a.
Kosmos 133	A-2	yes	4?	yes?	yes?	yes?	?
Kosmos 140	A-2	yes	4?	yes?	yes?	yes?	?
Kosmos 146	D-1-e	yes	3?	no?	yes?	no?	?
Kosmos 154	D-1-e	yes	3?	no?	yes?	no?	?
Soyuz 1	A-2	yes	4?	yes	yes	yes	?
Kosmos 159	A-2?	yes?	no?	yes?	no?	no?	no?
Kosmos 186	A-2	yes	4	yes	yes	yes	active
Kosmos 188	A-2	yes	4	yes	yes	yes	passive
Zond 4	D-1-e	yes	3	no	yes	no	?
Kosmos 212	A-2	yes	4	yes	yes	yes	active
Kosmos 213	A-2	yes	4	yes	yes	yes	passive
Kosmos 238	A-2	yes	4	yes	yes	yes	active
Zond 5	D-1-e	yes	3	no	yes	no	?
Soyuz 2	A-2	yes	4	yes	yes	yes	passive
Soyuz 3	A-2	yes	4	yes	yes	yes	active
Zond 6	D-1-e	yes	3	no	yes	no	?
Proton 4	D-1	n.a	special	n.a	n.a	special	mock-up
Soyuz 4	A-2	yes	4	yes	yes	yes	active
Soyuz 5	A-2	yes	4	yes	yes	yes	passive
Zond 7	D-1-e	yes	3	yes	yes	no	?
Soyuz 6	A-2	yes	4	yes	yes	yes	no
Soyuz 7	A-2	yes	4	yes	yes	yes	passive
Soyuz 8	A-2	yes	4	yes	yes	yes	active
Soyuz 9	A-2	yes	4	yes	yes	yes	no
Zond 8	D-1-e	yes	3	no	yes	no	?
Kosmos 379	A-2-m?	yes?	?	yes?	no?	no?	no?
Kosmos 382	D-1-m?	yes?	Special?	yes?	no?	no?	no?
Kosmos 398	A-2-m?	yes?	?	yes?	no?	no?	no?
Soyuz 10	A-2	yes	4	no	yes	yes	active
Soyuz 11	A-2	yes	4	no	yes	yes	active
Kosmos 434	A-2-m?	yes?	?	yes?	no?	no?	?
Kosmos 496	A-2	yes	4?	no	yes	yes	active
Kosmos 573	A-2	yes	no?	no	yes	yes	active?
Soyuz 12	A-2	yes	no	no	yes	yes	active
Kosmos 605	A-2	yes?	4?	no	yes?	yes?	no
Kosmos 613	A-2	yes	no?	no	yes	yes	active?
Soyuz 13	A-2	yes	4	no	yes	yes	no
Kosmos 638	A-2	yes	3	no	yes	yes	androgynous
Kosmos 656	A-2	yes	no	no	yes	yes	active?
Soyuz 14	A-2	yes	no	no	yes	yes	active
Kosmos 670	A-2	yes	no?	no	yes	yes	active?
Kosmos 672	A-2	yes	3	no	yes	yes	androgynous
Soyuz 15	A-2	yes	no	no	yes	yes	active
Kosmos 690	A-2	yes?	4?	no	yes?	yes?	no
Soyuz 16	A-2	yes	3	no	yes	yes	androgynous
Soyuz 17	A-2	yes	no	no	yes	yes	active
Anomaly	A-2	yes	no	no	yes	yes	active
Soyuz 18	A-2	yes	no	no	yes	yes	active
Soyuz 19	A-2	yes	3	no	yes	yes	androgynous
Kosmos 772	A-2	yes	no?	no	yes	yes	active?
Soyuz 20	A-2	yes	no	no	yes	yes	active
Kosmos 782	A-2	yes?	4?	no	yes?	yes?	no

NOTES

1. The table includes all flights which are known or suspected as possibly using Soyuz-related equipment, except for military photographic missions which currently may use some Soyuz components.
2. There is uncertainty as to the launch vehicles of a very few flights. Was Kosmos 159 put up by an A–2–e, or did it test the fully fueled tanks of a Soyuz service module? Did Proton 1, 2, and 3 go up on the D or D–1? Were the Kosmos 379, 382, 398, and 434 flights using an "m" version of their respective launch vehicles, or did they test the service modules of heavy Zonds?
3. There are indications that the shell of a Zond service module was the experiment carrier for the first three Protons, but this is not certain Likewise, Proton 4 seemed to have the shell of a special module with the mockup of a docking collar on it.
4. The torus tank for propellant was a standard feature of the Soyuz through 9 but not on the Zonds or the subsequent Soyuz flights. Only spherical tanks are carried on the majority of flights, cutting total delta V potential.
5. The doubts about Kosmos 605, 690, and 782 are whether they are modified Soyuz or earlier Vostok variants.
6. The work module is a routine part of Soyuz but not part of Zond.
7. Docking gear are shown to the extent known.

SOURCES: The record of flights as carried in the text of this report plus inferences, but with question marks added.

j. Soyuz Capacity and Mission Potentials.—In the earlier days of Soyuz flights, the Russians consistently attributed to Soyuz a capacity to fly as high as 1,300 kilometers and to stay in orbit for 30 days. Neither capacity has been demonstrated by a regular Soyuz in independent flight. The maximum stay time for a manned Soyuz has been 18 days (Soyuz 9, with a two-man crew), and the maximum altitude has been 384 kilometers (Soyuz 18). These discrepancies between announced capacity and demonstrated flight have led to many analytical studies in the West, since the Russians have not been forthcoming.[3]

An intriguing thesis was offered by David Woods that Soyuz was designed primarily to support a Soviet manned lunar program, preceded by Earth orbital tests and only later was consigned just to Earth orbital work. In his August 1974 analysis, he thought the volumes of the four spherical tanks and the one after-torus tank suggested use of UDMH and IRFNA, the same propellants used in the American Agena upper stage. He saw these tanks as carrying up to 3,275 kilograms of propellant, and with the estimated weight of the Soyuz, a capability to supply a delta V of 1.97 km/sec, much more than was needed for routine Earth orbit maneuvers, and essentially the same delta V as the Apollo 11 CSM (LOI, 892.1 meters/sec; LO, 48.0 meters/sec; TEI, 999.4 meters/sec; for a total of 1,939.5 meters/sec). He felt the match was too close to be coincidental.

Further, he suggested that the early Soyuz flights had been made only partially fueled, because the full delta V was not required in Earth orbit, and the A–2 launch vehicle would not lift the full load. He suggested that Kosmos 379, 382, 398, and 434 were full duration firings of the Soyuz propulsion system, with the weight brought within the capacity of the launch vehicles by leaving off the command module and the work compartment. He calculated the delta V of Kosmos 379 at 1.779 km/sec and of Kosmos 382 as 1.465 km/sec. Examining the Zond flights, which were without an orbital work compartment, but otherwise complete Soyuz, he calculated the delta V as 2.25 km/sec, which if fully fueled would have permitted going into lunar orbit and returning to Earth, even though in fact the flights were restricted to circumlunar tests. He suggested that some of the delta V capacity was used to shorten flight time and to minimize trajectory errors on these first test flights. After Soyuz 9, he assumed the Soyuz was reoriented to Earth orbital work, the torus tank was removed, and the fuel in the four spherical tanks was switched to nitric acid and hydrazine, cutting back the propellant weight to 1,325 kilograms. This would give Soyuz a delta V capacity of .685 km/sec, very close to the requirement for reaching 1,300 kilometers and return.

Saunders Kramer in a rejoinder to the Woods analysis saw the Zond flights as dependent upon the thrust of the escape stage of the D–1–e, not on the thrust of the Zond as well. Woods had mentioned that the delta V required for a lunar landing was 2.3 km/sec based on total propellant consumption for the LM. Kramer recalled an earlier NASA estimate of 6,000 ft/sec, equivalent to 1.83 km/sec. His own calculations on Kosmos 379, 382, 398, and 434 suggested they

[3] See particularly in Spaceflight, London, the following: Woods, David R., The Soyuz propulsion system, August 1974, pp. 300–302; Kramer, Saunders B., Soviet propulsion systems, January 1975, pp. 39–40; Gibbons, Ralph F., The Salyut family, April 1975; p. 159; Ashworth, Stephen, Origin of Soyuz, April 1975, pp. 159–160; and Oberg, James E., The hidden history of the Soyuz project, August/September 1975, pp. 282–289.

achieved about 1.83 km/sec, and hence could have been related to tests not of a Soviet flight to the Moon and return, but to a lunar landing and return to lunar orbit.

Stephen Ashworth challenged the Woods thesis on the grounds that Soyuz was not sophisticated enough to support lunar operations, considering its launch, navigation, propulsion, and environment control limitations. He cited disparaging comments carried in *Aviation Week* which appeared as ASTP-related Soyuz data became available. Ashworth did not explain how Zond variants of Soyuz could be used for circumlunar flights, although these flights were simpler than missions which additionally included lunar orbit or lunar landing operations.

The James Oberg review renews his theme published earlier that the Russians intended to be the first to land men on the Moon, also noting that Soyuz had been modified by omission of the work compartment, the substitution of a heavier heat shield, and the addition of a high-gain antenna, all of which required use of the larger D class launch vehicle rather than the A–2 since these payloads were sent around the Moon.

There are continuing studies of these issues, not yet in print. David Woods and Charles Vick are trying to refine our understanding of the Soyuz engineering with the help of new Soyuz data now available through the ASTP joint mission. Considering the fully fueled weight of Soyuz is beyond the capacity of the A–2 rocket, Vick wonders whether it was not planned from the outset that Soyuz would be launched by the D class rockets, with only preliminary, partly fueled tests using the A–2. There is no sign of any replacement for the A–2 as a launch vehicle for Soyuz permitting a fully loaded Soyuz to be launched, and the D class seems oversized for Earth orbital work by Soyuz.

k. Further Variants of Soyuz.—Soyuz evolution may still be continuing. Kosmos 670 and Kosmos 772 were man-related tests of unknown purpose. Kosmos 670 flew at an inclination not previously used by A–2, about 50.6 degrees, and it stayed up three days. Kosmos 772 flew at the ASTP inclination of 51.8 degrees and also stayed up three days. In November 1975, Soyuz 20 was launched at 51.6 degrees, and it spent two days making a rendezvous and docking with Salyut 4. As an unmanned ship, it was described as testing the possibilities for future ferry craft which could resupply stations, carry crews being rotated, or perform emergency rescues.

One further improvement in a ferry not yet demonstrated for sure is that of fuel transfer, although General Shatalov spoke of this in 1974 in Houston. Another useful step would be to enlarge the carrying capacity of Soyuz from the present two up to three or more. If indeed the Russians feel confident they can make a succession of ferry flights, unmanned in either or both directions, they may not need to adapt Soyuz to carry more than at present. Any real change would involve so extensive a redesign as to constitute a new ship.

l. Overall Design Considerations.—In retrospect, it is interesting to review the considerations which have shaped the capabilities of each of the manned craft to date, for the light this may throw on future developments. There have been fairly compelling issues in both the United States and the Soviet Union in this regard.

In the case of the United States, the Mercury was as much as the available Atlas launch vehicle could put up. It could carry only one person, and was intended to fly for three orbits, but was stretched with experience to a day and a half. The Gemini contract was let to the same builder on the ground that time would not permit a complete redesign, and establishment of know-how. While Gemini looked like Mercury, it was really a new ship, not only able to carry two persons, but able to open hatches for EVA, and having a service module and added instrumentation to permit rendezvous, docking, and a variety of other experiments, some in conjunction with the Agena target propulsion unit. The more powerful Titan II with storable fuels also added to capacity and flexibility. Apollo of course was designed to provide the tremendous fuel capacity, special power units in the form of fuel cells, self-contained navigational and general purpose computers, and docking equipment needed for working with the lunar module (LM) to make the lunar round trip. It could have been a complete dead end, when the lunar landings were terminated with a number of missions cancelled. But it was possible to adapt at great expense the shell of a S–IVB stage into the Skylab station, another very useful but dead-end project, and then the over-qualified Apollo, by limiting the fuel carried was available for ferry visits to the Skylab, and later to meet with the Soyuz in the Apollo-Soyuz Test Project (ASTP). Now Apollo has joined Mercury and Gemini as a museum exhibit only, along with the Saturn launch vehicles which no longer are manufactured and which no longer fly, even though they exist in mothball stockpiles.

The question is whether the Soviet program shows the same series of ad hoc decisions or whether a longer range plan has dominated their thinking. Vostok gives some evidence of being dead-ended. Indeed, the spherical capsule most closely resembled in general characteristics a high-altitude balloon capsule of the 1930's, plus ablative shielding, and a service module mostly loaded with chemical batteries. Voskhod was no more than Vostok with the ejection seat replaced by several seats to crowd in a multiple-person crew. Without the ejection system and manned parachute landing used with Vostok, the Voskhod carried some risks in abort situations, and required an extra rocket landing system just before touch-down to cushion the hard blow of land impact. America throughout has been limited to water landings, although there was talk of paraglider landings beginning with Gemini which were eliminated from the program as costing too much time and adding other uncertainties. Soyuz gives the first signs of being a better planned ship for a sustained space effort, and the discussion in Chapter Three as well as this chapter demonstrates that it has many limitations and compromises. Zond for circumlunar manned flight is clearly built of Soyuz elements, and the debate which will emerge in this chapter is the extent to which Soyuz or Zond was originally intended to be the main stream of Soviet development, at the time planning originally was done.

The American Shuttle is designed to be our sustainable effort, and it has been compromised in a number of respects for both fiscal and technical reasons. We have yet to explore how long the Russians will stick with Soyuz derivatives, and when they will create a new Earth orbital manned system.

2. Salyut

Salyut falls well short of Skylab in the amount of space it provides, although the parallel agenda of experiments carried out in each superficially seem much the same. The big advantage of Salyut is that it is ongoing and evolving while the one orbiting Skylab after three successful visits of growing length continues its ghostly flight in effect a derelict. Its backup was not launched for budgetary reasons.

By now there have probably been as many as six Salyut launch attempts, and these already include at least two programs. The evidence for these two programs was summarized by Sven Grahn of Stockholm.[4] Grahn had correctly forecast the Salyut 4/Soyuz 17 mission before its launch by noting the higher orbit selected in the earlier Soyuz 12 test; and similarly he forecast the Salyut 4/Soyuz 18 mission by noting the earlier 60-day stay time, powered down, of Kosmos 613.

a. Military Salyut.—Grahn noted that the military version of Salyut flies in a low circular orbit, using frequencies and telemetry formats common to military photographic recoverable missions. Based on past experience, we should see more such flights, with military crews entering them from time to time to calibrate instruments and reload cameras. Salyut 3 already has demonstrated it could send back a capsule loaded with film and other data, and this should be a continuing feature. Life time may be extended well beyond six months or a year by refueling the station, which otherwise would tend to decay from its relatively low orbit, if its propulsion system were not fired periodically.

b. Civilian Salyut.—The civilian version of Salyut can also operate in automatic mode, but at its higher altitude will tend to have a longer life, building toward the day of "permanent" stations. Flying at this higher altitude, it will expend less fuel in maintaining the orbit. Already demonstrated to a stay time of 63 days for a single crew, this period may be extended, as they pursue geophysical, astronomical, solar, Earth resources, and biological studies.

What is not clear is whether this particular class of station has grown or will grow in size. Soviet releases suggest that from the combined length of Salyut 1/Soyuz 11 at 20 meters, the length grew to 21 meters for Salyut 3/Soyuz 14 and to 23 meters for Salyut 4/Soyuz 17. But changing the basic shell would be very costly for any benefits gained. It now seems most likely they have been the same size, but different inclusions in the length have accounted for the variations. The Western notion that Kosmos 557, a failed civilian Sayut, was bigger than Salyut 1 may be influenced by the greater optical brightness caused by the larger area of solar panels which the later stations have carried. These three steerable panels have a greater surface than the four fixed position panels used on Salyut 1.

Even though it has not been put to use yet, the addition of a large hatch for EVA work on the newer Salyuts may be a portent of activities to come where cosmonauts will work in free space.

c. Salyut as a Component.—Just as some Western speculation is that Soyuz was designed to be a component part of some larger construction in space, it is also a possibility that at some point Salyut also was so regarded. For example, the G class launch vehicle could put a Salyut

[4] Grahn, Sven, Salyut variations. Spaceflight, London, March 1975, p. 118. This was a follow on to his earlier article, Future Salyut missions, Spaceflight, London, October 1974, pp. 392–393.

into lunar orbit for manned survey of the Moon, or could carry men into a Molniya-type inclined, eccentric orbit, or into 24-hour synchronous orbit. In some of these missions, it might have to be combined with other components. This especially would be true if it became part of a manned lunar landing mission. This will be discussed below. It might also become a component in a larger space station assemblage in Earth orbit, and this will also be discussed below.

d. Large Conical Instrument Container.—One of the elements of adaptability which has made the Salyut station versatile and opens up its future uses as well is the big conical structure which is mounted transversely in the largest diameter part of the cabin, and this cone at its wide base opens into space. Like a big icecream cone, it can be stuffed with different flavors. Flying in low orbit, and with the Salyut rolled to point the base of the cone downward, it provides space for the folded optics of a high-resolution camera system. When the ship is flying in higher orbit, and it is rolled to point the base of the cone outward, it can be used to carry a different package to conduct solar studies, or astronomical studies. Since the solar panels now are automatically oriented to point toward maximum sunlight as they swivel up to 180 degrees, either orientation for the cone can be sustained at all times without relying upon chemical buffer batteries alone during some maneuvers. Inside the station, a crew member mounts a chair to the viewing eye pieces and controls which pierce the cone, and connect with the inserted instruments.

e. Docking.—So far, only one docking port has been provided on the Salyuts which have been pictured. It would seem that flexibility of use would be increased if there were more than one port. It would permit the easy transfer of more than one crew, and simplify other ferrying operations without adding much to the risk of a crew in residence. Fuel transfer would seem to be easier if done at the opposite end of the station where the fuel tanks and propulsion units are located.

However, Bushuyev was in Houston at the time of the docking of Soyuz 20 in an unmanned flight with Salyut 4, and he suggested it was entirely feasible to contemplate ferry trips that might take a crew to the station, leaving them there while the Soyuz with film, tapes and experimental results returned to Earth and a later automatic Soyuz could come up to collect the crew when they were ready to return to Earth. This sounds a little hazardous as a routine procedure, considering the number of docking failures which the space program has experienced. Obviously, the automatic mission would be a useful technique to have in reserve for some kinds of rescue situations, but as a routine substitute for adding a second docking port seems less desirable.

f. International Cooperation.—Salyut today has only the standard Soviet passive docking gear. Perhaps in the future that will be retained for the military version of the station as an added assurance of no unwelcome visitors. But perhaps the civilian Salyut in time will adopt the androgynous system used for ASTP. This would permit docking by future American Space Shuttles as well as Soyuz craft. Station crews of the future may include Russians, Americans, and nationals of other countries.[5]

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[5] See Oberg, James E. The legacy of Apollo-Soyuz, Analog, New York, August 1975, pp. 27–36.

There is one ironic fact about the American Shuttle. While it is a logical ferry vehicle, which could go to visit a Salyut, it is also so large that a complete Salyut could be carried to orbit in the cargo bay of the Shuttle!

3. A Long-Term Space Station

The Russians for many years have said they would establish long-term space stations with larger crews and long stay time for the crew, as well as using crew rotation.

a. Single Launch.—The simplest way to put up a larger station would be to use a G class launch vehicle. This would be similar to the launch of Skylab using the Saturn V. This larger station would have the potential of being more versatile than Salyut, launched by the D class vehicle, but like Skylab would have an early limit to growth as an isolated unit.

b. Multiple Launches.—Just as the U.S. program has considered in the future putting up a succession of station components in Shuttle flights, the Russians have also talked about multiple launches of units which could be assembled in space to create a larger station. Without a reusable shuttle, any rapid build-up would be an expensive proposition, if using the D class launch vehicle. One can also envision the use of the G vehicle to put up a large starter unit to which other D-launched units would be attached. A Soviet design concept drawing released some years ago showed a hub to which four A–2-launched Soyuz were attached. One can also see a system in which four Salyut stations might be attached. But the Salyut, probably designed primarily for independent operations would not be the ideal building block for a long term, large station. If the decision were to go to a ring assembly to provide a more useful artificial gravity than spokes provide, a station unit that could be moved around by space tug and which had air locks and docking attachments at least at each end and perhaps in other locations would be more convenient to use. This shape of unit with multiple ports would be more akin to the U.S. Space Task Force plan that called for a universal station component which could be used not only in low Earth orbit, but in synchronous 24-hour orbit, in orbit around the Moon, on the lunar surface as a habitat, and for manned voyages to the planets.

c. Other Orbits.—As already mentioned, the Russians might use Salyut or a new large station in other orbits from those flown so far. They have mentioned that a polar orbit to give world coverage will be required sometime. In recent years, all manned flights have been at an inclination of 51 to 52 degrees. More exotic orbits perhaps will not come as operational modes until a new station component is available.

d. Near Term.—The Salyut station may be stretched to extend its useful life for two or more years. Perhaps crew size could be doubled to four persons without too much trouble, considering it was designed for three originally, even though it has been operating with two since Salyut 3. Automatic resupply should make this crew growth easier to attain.

e. Longer Term.—Much larger stations almost certainly will require assembly, and Soviet spokesmen have mentioned crews in the range of 12 to 20 as a realistic early goal, with stations of much larger

size not needed for many years. Crew stay times may be extended to six months or even a year. Longer stay times would cut operating costs, and would also be the training ground for the development of future planetary missions that might come in the late 1980's or in the 1990's.

4. Reusable Space Shuttle

These have already been discussed in an earlier section of this chapter looking at launch vehicle capabilities. If the Russians make the decision to develop a reusable space shuttle, as they may already have done, it will be able to support the creation of an orbital launch assembly and checkout station to support flights to the Moon and to the planets.

In his review article, Kramer predicts routine use of a Soviet space shuttle by 1982, with a lifting capability of 30 to 45 metric tons.[6] That time estimate seems as reasonable as any other which has been offered, although it must be noted there is no hard evidence in the public domain of such development. But then, the U.S. Shuttle which should be flying sooner would also still be secret under Soviet-style information policies. Perhaps the larger question is not so much Soviet desires for a shuttle but some of the materials, quality control, aerodynamics, and computer technology that bring the shuttle within reach, and here we are less certain of Soviet capabilities.

5. Zond

The Zond circumlunar flights of a manned precursor as we have seen them probably will not be renewed in their previous form. The program either was marginal or was only a component in some larger lunar program which has also been delayed or redirected. Estimates by Westerners suggest that Zond without an orbital module would support only one man for circumlunar flight of about six days. Since the test flights lasted seven days, it is possible the six day estimate is a little low. In any case, this analysis suggests the cosmonaut would be little more than a passenger on an automatic ship.[7]

Hence, it would seem that such a flight standing alone would be useful only to establish a world first, and after Apollo 8, that opportunity was lost. In world image, the value shrank rapidly, as it could not confer equality, let alone primacy, with multiple-man Apollo crews doing more and more in the vicinity of the Moon and then on the surface. However, if Zond was indeed a step toward more ambitious Soviet lunar activities, then it was worth continuing without regard to the American successes so long as there was any immediacy to these larger Soviet plans. But Zond ran its course as an engineering test supplemented by picture-taking and service as a carrier for biological specimens.

6. *Manned Lunar Landing*

a. Background.—Several of the foregoing sections have touched at least obliquely on the manned lunar landing program. Also Chapter Three of this study developed an account of possible lunar-landing-related events up to 1969 when the Russians announced that immedi-

[6] Kramer, Saunders B., op. cit., p. 250.
[7] Oberg, James E., The hidden history of the Soyuz project, Spaceflight, London, August/September 1975, p. 284.

ate plans had been set aside. Now it is time to reexamine these issues in the light of past events and capabilities for what light they may throw on the future.

The report corresponding to this one which covered the years 1966–1970 concluded there was a Soviet manned lunar landing program. Some Westerners thought such a program had lost its steam as early as 1966, and hence the United States was not "racing" with Apollo after that time. The report findings, however, were that the net balance of evidence was the Russians were still desirous and even hopeful of being first to land men on the Moon right up to the time of the landing by Apollo 11. While a few Soviet statements of the period are carried in Chapter Three of this report, a much longer and possibly compelling list was contained in the 1966–1970 report on pages 359–384. For the Russians to have been successful in this regard, there would have had to have been a conjunction of two types of events: A serious delay or accident in the Apollo program; and a number of near-flawless Soviet development flights. For example, the 1966–1970 report noted, the United States was willing to send men to lunar orbit on the third flight of a Saturn V, a vehicle never sent previously unmanned to the Moon, and men were landed on the third lunar vicinity flight of this vehicle. Had the Russians been willing to send men to the vicinity of the Moon on a third lunar flight of the G–1–e launch vehicle, following two fully successful unmanned flights, with these unmanned flights starting in late June or early July of 1969, then they might have reached at least orbit of the Moon with men as soon as the late fall of 1969 or winter of 1970, and perhaps even made a landing. But the report added the observation that of course the G–1–e had not been successful, and also noted that there was not enough evidence available to establish how the Russians would have executed in the engineering sense the culminating lunar landing mission.

Chapter Three in this report has touched briefly on Soviet abilities to do rendezvous and docking, to make limited circumlunar flights with the D–1–e and Zond, and the rumors about the G–1–e very large launch vehicle. Recent studies by Western analysts writing primarily in *Spaceflight*, the organ of the British Interplanetary Society, are exploring in greater detail some of the possibilities which the Russians may have been working toward in the late 1960's and what lies ahead. It is the purpose of this section to review these suggestions for what insights into the next several years they give.

b. Requirements.—The ingredients of a successful manned lunar landing round trip are now known and have been met by the U.S. Apollo program. While the details may differ, as there are several engineering options, the basic logic of attaining a reasonable chance for success at minimum cost is fairly universal and would apply to a Soviet program as well as American.

(1) There must be a launch vehicle with appropriate upper stages capable of lifting sufficient weight and providing sufficient delta V to fly a habitable ship to the Moon, land, and then return crew and gear to Earth. If one vehicle is incapable of performing the entire mission lift, then there must be multiple launches and use of rendezvous and docking of components sent up separately.

(2) Options on rendezvous and docking, made necessary by the almost overwhelming sizing problems with a single launch, include

considering Earth orbit rendezvous, lunar orbit rendezvous, lunar surface rendezvous, and even lunar in-transit rendezvous (once urged by a minority in this country).

(3) Whether done by direct flight or through rendezvous and docking, there is a place for specialized modules not only for propulsion but for manned support and other payload and control devices to and from the Moon, in lunar orbit, and for descent to the lunar surface and ascent again from the lunar surface.

(4) Assuming that rendezvous and docking of various propulsion and specialized modules are necessary, then a successful program requires a demonstrated ability to do such work accurately and in timely fashion in the places selected by the mission planners. As is known, Apollo used lunar orbit rendezvous (LOR) successfully, but over the protests of an influential group of advisors who preferred Earth orbit rendezvous (EOR).

(5) With or without rendezvous and docking, the mission requires well developed tracking and high capacity communications systems, preferably functioning 24 hours a day and uninterrupted in line of sight by the rotation of the Earth. Not only must there be a large computational facility on Earth, able to work virtually on a real-time basis, but the lunar expedition should have a self-contained computing and navigational ability to work independently of reference to surface features of the Earth.

(6) Both for reasons of safety and for gaining maximum scientific advantage, there must be adequate mapping of the Moon to understand surface conditions, to select worthwhile targets for investigation, and to insure successful landings. A knowledge of lunar mascons is important to celestial mechanics calculations as well as being able to locate and maneuver precisely the ship or ships in three dimensional space near the Moon. It is also important to understand the interacting gravity forces of multiple natural bodies in space.

(7) There must be adequate life support systems both during the flight and on the lunar surface, with adequate cleansed air of the right constituents and pressure and with attention to contaminants and outgassing. There must be potable water, food, waste management, proper temperature controls, and radiation protection, including recognition of the possibility of a solar flare during the mission. Also, attention must be paid to maintaining inner ear function for orientation and well-being, good muscle tone, body coordination, and accurate perceptions during the varied conditions of weightlessness, low gravity, and acceleration including high G load.

(8) There must be a thorough engineering study and practical reliability to handle the several problems of applying ship accelerations, making fine corrections of orbit and velocity, joining stages with secure locks and tight seals, managing boil-off of cryogenics, avoiding deterioration caused by corrosive fuels, achieving sure ignitions at only the right times, insuring even propellant burning and balanced chamber pressures, providing leeway for shortfalls in some engines, getting clean separations by explosive bolts, and having a thorough understanding of the interactions of ships, systems, and natural forces, in each of many kinds of maneuvers and operations.

(9) There are special problems of Earth return that go beyond Earth orbital flight. The returning ship must be in a narrow corridor, with the operators recognizing that too steep a return will burn up

the ship while too shallow an approach will send the ship skipping out into space not to return with the crew still alive before consumables are exhausted. The best of returns involves problems of dissipating high heat loads, spreading deceleration to avoid peak G loads, and finally maneuvering to a suitable recovery area, with contingency survival plans to meet any conditions of ocean or land.

Undoubtedly any systems study of the entire mission elaborates these requirements into tens of thousands of pages of detail almost all of which are important to a successful mission. The public probably does not comprehend how far human organization and planning had to go to provide successful Apollo flights beyond the building of giant rockets and the selection and training of highly motivated astronauts.

c. Assessment of Soviet Capabilities.—James E. Oberg wrote an assessment which dealt with some of the requirements mentioned above.[8] His title reveals his conclusion. He pointed out that up to the middle of the 1960's, neither the United States nor the Soviet Union had demonstrated accomplishment of any of the lunar requirements, except that the United States was coming along with a global tracking and communication network. During the second half of the 1960's, the United States obviously met all the requirements, since it was successful in a series of Apollo landings. During the same second half of the decade, the Russians began to demonstrate the establishment of essential elements as well. They demonstrated unmanned circumlunar flight with Earth recovery, but had not yet done lunar orbit with Earth return, and their lunar landing and return demonstration which came in 1970 was a proof of principle but only with a very small soil sample returned under very high G load conditions, not anything related to a manned flight. The tentative conclusion which Oberg reached, and which seems reasonable, is that the Russians had demonstrated a manned circumlunar capability through the Zond program, but lacked confidence the system was sufficiently man-rated to send a cosmonaut. Second, they might have demonstrated in 1969 an unmanned flight to lunar orbit and then Earth return of a ship capable of carrying a human crew, if the G–1–e vehicle had not failed in its launch. If done, a manned lunar orbit flight, roughly equivalent to Apollo 8 might have come by 1970. Third, work to develop a manned lunar landing capability was well along, but its timetable and operating mode are harder to determine.

Oberg based his conclusions on what we know about the performance of the A–2 and D–1–e launch vehicles and what NASA officials were saying about the new G–1–e vehicle. Soviet tracking support was greatly improved through the construction of large tracking, communications, and command ships with specially stabilized antenna platforms, and using the Molniya satellites to keep the ships in touch with the main Soviet space center. They also demonstrated a growing capability to guide and control at lunar distances, and to do rendezvous and docking in Earth orbit. They had flown long enough for an 18 day lunar mission if needed, and they had demonstrated a self-contained space suit free of life support umbilicals. They demonstrated an ability to return from lunar distance, cutting the G load, absorbing the heat load, and steering to home territory by skipping out of the

[8] Oberg, James E., Russia meant to win the Moon race, Spaceflight, London, May 1975, pp. 163–171, 200.

atmosphere after a southern approach over the Indian Ocean. This list of accomplishments would not be convincing as a complete foundation for manned lunar landing, but it probably could have supported manned lunar orbit. Perhaps some of these listed Soviet capabilities were marginal, but they seemed to be checking off requirements in much the same fashion that NASA was constructing and testing its own building blocks.

Obviously the outstanding success of Apollo 8 took the edge off the Russian goal, and they could not be first to do a circumlunar mission or lunar orbit. If there was a lunar landing program for the Russians to make it to the Moon sometime in the years 1970–1972, then the competitive aspect was blunted by the fact that Apollo 11 was successful, and Soviet hopes for any near-time success must have been totally destroyed in the explosion of the first G–1–e as it was to be launched to the Moon. Suppose the Apollo 8 mission had had the experience of Apollo 13 when there was an explosion in the Service Module. Without the Lunar Module lifeboat, the Apollo 8 crew would have died before return to Earth, and there would have been no Apollo landing in 1969 or any other time soon, for reasons of practical politics if not engineering. Suppose any of a thousand things had aborted the Apollo 11 landing, killing the crew.

The Apollo project would again have faced the threat of indefinite delay. If the G–1–e vehicle had worked in the 1969 time frame, and with Apollo at least temporarily hors de combat, then it seems possible that we would have seen an acceleration of testing of Soviet subsystems which if successful might have led to landing men in the early 1970's, the first to do so. While Oberg saw the G–1–e as capable of supporting manned lunar orbit and return, he did not make a detailed case for Soviet manned lunar landing. The Russians do not discuss in advance such programs in engineering terms; and having delayed or cancelled the postulated original landing program, we cannot expect them now to help us interpret what they might have done.

d. Components and Alternatives.—Current Western analysis does not provide a single answer that is satisfying and unique to explain how the Russians might have landed men on the Moon. Some of the debates on this topic are relatively recent, and these suggestions will be reviewed.

More analysts than not believe that Kosmos 379, 382, 398. and 434 were related to the Soviet manned lunar program, but they do not agree as to precisely what that role was. Even though current plans for flights of Soviet men to the Moon may have been dropped from the agenda in the summer of 1969, the program seems to have had a certain momentum. Hence after that time came the flights of Zond 7 and 8, and the four Kosmos flights just referred to, as well as strong rumors of continuing work with the G–1–e vehicle. Possibly related to the Moon were the flights of Soyuz 6. 7. and 8. Some would add to the list the work with Soyuz 9 and the early Salyut and its Soyuz ferries as well.

Sven Grahn of Stockholm identified the four Kosmos flights named in the paragraph above as possible lunar landing craft.[9] His assumptions were that the total delta V demonstrated by each of the four

[9] Grahn, Sven, A Soviet lunar spaceship, Spaceflight, London, October 1973, pp. 398–400.

flights were as follows: 1.797 km/sec; 1.732 km/sec; 1.563 km/sec; and 1.628 km/sec. Working with an estimated weight in low Earth orbit of 7,000 kilograms for the three A–2-launched spacecraft, he suggested they were partially fueled lunar modules, made up of a descent stage (which the Royal Aircraft Establishment (RAE) labeled a "platform" in its records), and an ascent stage (which the RAE called a "payload"). He noted that the Earth orbital carrier rocket stage was the usual 2.6 meters diameter by 7.5 meters long. The possible descent and ascent stages probably had the same 2.6 meter diameter and a combined length of 5 meters. His measurements of delta V for the three possible descent stages were: 0.265 km/sec; 0.254 km/sec; and 0.283 km/sec. This would represent partial fueling as that is not enough delta V to demonstrate a lunar landing. The ascent stages were tested at enough fuel load to give sufficient delta V for return to orbit, but may not have had their payload complete. They showed delta V's as follows: 1.532 km/sec; 1.309 km/sec; and 1.345 km/sec. He noted the dry weight of the American Lunar Module (LM) was about 5,000 kilograms. Hence if the Soviet equivalent had been flown without life support gear and landing legs, it is possible its weight could be held to 7,000 kilograms and still have been partly fueled.

Grahn then looked at the flight of Kosmos 382, which followed eight days after Kosmos 379. It was launched by a D class vehicle, and the Earth orbital carrier rocket remained attached to the payload for 5 days, during which time it made either two or three burns. This rocket was estimated as 4 meters in diameter and 12 meters long. After separation, the payload made other maneuvers. The RAE again listed a "platform" and a "payload". The RAE suggested the payload was a 5 meter sphere, but it would not be unreasonable to assume that the diameter of the two objects was closer to 4 meters, and that perhaps the "platform" was a service module and the "payload" a command module. Their combined length might have been about 10 meters, with that divided 6 for the service module and 4 for the command module. Perhaps the service module had solar panels.

Grahn continued that if the two types of hardware (A–2 launched and D–1 launched) had been brought together, we might have seen a Soviet Command and Service Module (CSM) and a Soviet LM joined to make a total structure 16 meters long, with a maximum diameter of about 4 meters, not counting solar panels. This would compare with the NASA equivalent CSM–LM combination whose CSM diameter was 3.91 meters and whose combined overall length was 14 meters, not counting legs.

It may be recalled that in this study, it has been recognized that the several maneuvers of these ships were more than we were used to seeing with the A–2 or D–1 launch vehicles, and hence their launch vehicles were tentatively classified as A–2–m, and D–1–m. It is not possible to resolve such issues of staging and propulsion to a certainty, and the Grahn thesis seems internally consistent, even though opening up other possible interpretations of labels for these particular launch vehicles.

It may also be recalled that earlier in this chapter it was pointed out that David Woods came to a different conclusion about these four flights.[10] His calculation of delta V for Kosmos 379 at 1.779 km/sec is

[10] Woods, David R., The Soyuz propulsion system, Spaceflight, London, August 1974, pp. 300–302.

very close to the 1.797 km/sec calculated by Grahn. But his calculation for Kosmos 382 came out to 1.465 km/sec, under the 1.732 km/sec of Grahn. He saw them as full-duration firings of the Soyuz propulsion system, and he had already advanced the thesis that Soyuz itself was designed to fly from Earth to lunar orbit and back to Earth, because of its inherent high delta V when fully loaded.

As far as the lunar landing itself was concerned, Woods assumed the propellant loading equivalent delta V from lunar orbit to surface and back to lunar orbit to be 2.3 km/sec each way, while Grahn assumed it was 3.3 km/sec for both. As already pointed out, Kramer quoted earlier Apollo 11 estimates for the descent where the delta V amounted to 1.83 km/sec.

At the time of the Kosmos 379 flight Perry calculated that the two maneuvers entailed delta V's of 0.4 and 1.4 km/sec respectively.[11] NORAD did not report a low initial orbit for Kosmos 382, but Perry noticed that the initial Equator crossing of that flight was too far east by 9° for the first NORAD-listed orbit to have been true. A month or so later, he realized that the delta V's for LOI and TEI of Apollo 11 totaled the same as the delta V's for Kosmos 379, and that the second delta V for Kosmos 382 was, as in the case of Kosmos 379, also 1 km/sec. The perigees of these flights were in opposite hemispheres, presumably because the first experiment involved perigee burns to make the orbit more elliptical and therefore perigee was placed in the region of the Tyuratam launch site. But the second experiment required an apogee burn to raise perigee, and hence the apogee was in the northern hemisphere where the burn could be controlled and monitored more easily.

In the case of Kosmos 382, Perry calculates that the initial parking orbit was 303 by 180 kilometers. Using a restartable upper stage of the D vehicle, the orbit was adjusted to the eccentric pattern reported by NORAD, probably with a delta V of 1.0 km/sec. The change from the initial NORAD-listed orbit to the intermediate orbit required a further delta V of 0.27 km/sec. For the final maneuver, Perry originally assumed a plane change of 4.3°, the difference in inclination, but this assumed the change occurring at the Equator and gave a delta V of 1.0 km/sec. However, on realizing that the plane-change would take place at apogee, near the northern apex of the orbit, he showed that the necessary change in azimuth would be nearer 14° if carried out at 50°N latitude. This means a delta V of 1.6 km/sec, or even more, and comes very close to the Sven Grahn calculation.

More recently, Perry calculated two burns, each of a delta V of 2.4 km/sec, for Kosmos 737, the first geostationary Kosmos.[12] This suggests that the Kosmos 382 was most probably lunar-related rather than geostationary.

From these several estimates, it is evident that these Western analysts are making different assumptions so that they do not come out with universally agreed-upon figures which can be linked to any one explanation. But in general, at least the flights of Kosmos 379, 398, and 434 probably generated enough delta V to be tests of the steps to move from an Earth-Moon trajectory (TLI) into lunar orbit (LOI) and from lunar orbit to Earth return (TEI), or alternatively, to

[11] Perry, G. E., Flight International, London, *98*, 923, December 10, 1970.
[12] Perry, G. E., Flight International, London, *105*, 439, April 4, 1974.

move from lunar orbit to lunar landing and back to lunar orbit. Kosmos 382 could also have been testing LOI and TEI. Of course there remain many other questions about these flights, including whether any close examination of these maneuvers in their combinations of amount of thrust and delta V reproduced any of the requirements to simulate the profiles of any part of actual lunar missions.

It will also be recalled that in previous pages, Woods had shown that even the Zond modification of Soyuz, by leaving off the work compartment, may have had a lunar orbit and return (LOI, TEI) capability instead of just circumlunar. However, if operating alone, it would have strained the life support capability for one man, if it invested more than six days for the total flight.

Phillip S. Clark also saw a connection between these four Kosmos flights and the lunar program.[13] He noted that the A–2-launched Kosmos 379 might have been a test of a fully-fueled service module of a Zond, with its weight held down to Soyuz size (6.6 metric tons) by leaving off the command module. If the command module (about 1.3 metric tons) had been present, the combined weight of the whole Zond and its fuel load would have been about 8 metric tons. He suggested this heavy Zond might have been sent on a mission to the Moon by an uprated D class launch vehicle which he tentatively called a D–2–e. He also suggested that for the Russians to do more than an absolutely minimal manned lunar mission they might use the G–1–e launch vehicle to place a 20-ton Salyut in lunar orbit, and then a D–2–e-launched heavy Zond would serve as a ferry from Earth to reach the lunar orbiting station and to return to Earth.

Woods, in his review of the Soyuz propulsion system, suggested that the Soviet approach to lunar landing would be very similar to the NASA Apollo method including lunar orbit rendezvous, except that the lunar landing module would be placed in lunar orbit and waiting there before the arrival of the manned vehicle which was flying from Earth to lunar orbit. He saw the Soviet lunar landing module as perhaps capable both of ferrying men to and from the lunar surface and also of being used for one-way flights to the surface to land additional supplies (another lander).

James E. Oberg in his review of the Moon race[14] noted the reverse nature of the early Soviet docking exercises. Instead of putting up a target and then launching a chase spacecraft to be the active partner, they did just the opposite. They launched the active ship first, then sent up the target, as if the target were a rehearsal for putting up a propulsion module with either cryogenic or corrosive propellants which could not afford to sit for an extra period in Earth orbit awaiting the launch a day or two later of the active ship. He suggested the intent was to launch three men with an A–2 to place a Soyuz in orbit. Then a D–1–e would put up a propulsion unit to which the Soyuz would dock, giving the Soyuz the added thrust required to go to lunar orbit. He saw this as a way of attaining a lunar orbit with the option of staying in such orbit for a week or so: Soyuz 9 on its 18-day flight simulated a round trip to the Moon of 3 or 4 days each way, plus about 10 days in lunar orbit. Oberg also noted that since

[13] Clark, Phillip S., The Soviet lunar programme, Spaceflight, London, February 1974, p. 79.

[14] Oberg, James E., op. cit., Spaceflight, London, May 1975, pp. 163–171, 200.

the Soyuz manual phase of docking requires use of a periscope, occasioned by the mid-position of the command module, the periscope could as easily be swiveled around to point backwards as well as forwards, and he also noted that early Soyuz ships carried radar transponders facing both forward and aft. Cosmonaut Beregovoy is said to have started to describe the ability of Soyuz to dock at either end when President Keldysh of the Soviet Academy cut him off abruptly. Oberg added other bits of circumstantial evidence: The use of a self-contained space suit with back pack, instead of simpler life support umbilicals as used by the early American space suits, might have been an early commitment to lunar work where such self-containment would be necessary for surface exploration. Another item: Soviet cosmonauts are said to have begun helicopter training in 1967—just as the Apollo astronauts did if they were slated to land LM vehicles on the Moon.[15]

e. Unpublished Studies.—David Woods has continued his studies of Soviet lunar capabilities, and has prepared a new paper not yet published which amends, elaborates, and refines his earlier published efforts. He now sees all versions of the Soyuz, with or without the torus tank, as carrying nitric acid and hydrazine propellants. He suggests the torus has three tanks within it, never taking full advantage of its volume, and probably designed to be jettisoned during flight. (A Vick concept.) He suggests a void between two nitric acid tanks may have housed electronics. (A Houtman concept.)

His calculation is that the propellant capacity of the torus is 1,815 kilograms at full load and that of the four spherical tanks is 1,150 kilograms at full load. In the case of Kosmos 159, he suggested this full load was carried within the lifting capacity of the A–2 by leaving off both the command module and the orbital work compartment. Then, in the case of Zond 4–8, he suggests not only was the work compartment left off but also the torus tank. He has developed detailed weight and component tables for all the classes of the Soyuz seen to date, for the circumlunar early Zond (4–8), and for a postulated "heavy Zond" which would have restored the torus tank and given it a full propellant load for an all-up weight of 7,825 kilograms—somewhat beyond the estimated Earth orbital lift capacity of the A–2 or the translunar capacity of the D–1–e. He suggests that the lighter, demonstrated Zonds probably had a delta V of 625 meters/sec, not enough to go into lunar orbit and out (LOI and TEI), but enough to cut flight time and to refine the accuracy of the flight path, improving the precision of the flight around the Moon and of reentry into the atmosphere of Earth.

Woods suggests that the demonstrated Zond series were primarily to test the Earth return phase of future Moon flights. His impression is that the first three Proton satellite flights were engineering tests of the D–1 vehicle, carrying an external mockup of the heavy Zond service module, and Proton 4 roughly a sphere close to 4.5 meters in diameter with a mockup of a docking collar to simulate a man-carrying capsule the G vehicle might carry in its future lunar use.

By applying a least-squares fit to a variety of available official Soviet weight summaries he derives the approximate dry weight of the escape stage of the D–1–e launch vehicle. It comes out as 2,185 kilo-

[15] Collins, Michael, Carrying the fire, New York: Farrar, Straus and Giroux, p. 280.

grams. This indicated the D–1–e escape stage is hydrazine/nitric acid fueled, in order to attain the I_{sp} ratings required for the current deep space Luna and Mars missions. The total Earth parking orbit weight of such a mission is projected to be approximately 23,240 kilograms. Then he sees tradeoffs between propellant weight and payload weight, depending upon the mission delta V requirements.

Woods repeats his estimate that any Soviet manned lunar lander would have to be carried to the Moon separately from the principal launch, but that the components should be possible to test in Earth orbit using the D class launch vehicle, even as the NASA program tested in Earth orbit components launched on Saturn IB which later were sent to the Moon by Saturn V. With the American experience as a guide, he has set the weight for the combined ascent and descent Soviet lunar landing vehicle at 20,000 kilograms. This compares with the LM of Apollo 11 at 15,059 kilograms. One reason for the larger weight is related to the inclusion of solar panels to unfurl at the lunar surface, and an airlock.

Woods sees the total lunar spacecraft as consisting of three modules, more than possibly could be carried by the D–1–e for a direct landing, and probably more than could be carried by the G–1–e as well, based upon available estimates of its capacity. Woods suggest (1) a 20,000-kilogram LM, made up of a fueled ascent vehicle of 5,812 kilograms and a fueled descent vehicle of 14,188 kilograms; (2) a habitat for use in lunar orbit, as well as flight to the Moon, with a weight of 2,000 kilograms; and (3) a heavy Zond for flight to the Moon, use in lunar orbit, and for return to Earth, that vehicle to weigh 7,825 kilograms. The mission would start with a G–1 launch of the propulsion module; to it would dock a D–1–launched payload—the habitat and lunar lander. The final launch would be an A–2 heavy Zond with a 3-man crew. The propulsion module of 135,000 kilograms would function much like the American S–IVB stage and service module of Apollo. This propulsion package would drive the combined assembly to the Moon and place it in an initial orbit there. He saw the A–2 vehicle as capable of carrying a heavy Zond to Earth orbit by placing it within a smaller, more streamlined shroud than that used for Soyuz which has an orbital work compartment unlike the Zond. This shroud has appeared in Soviet photographs, so is known to exist.

While the total Earth orbital weight would be 164,825 kilograms after three launches, the step of trans-lunar injection (TLI) would reduce the gross weight to 60.4 metric tons, within the 60–70-metric ton range cited by Soviet Cosmonaut leader General Kamanin in 1967 in his prediction of what kinds of weights he saw as routine for flight to the Moon within five years of 1967. A second burn of the propulsion module would brake it into lunar orbit (LOI), where the propulsion module would be cast off. The heavy Zond would lower the periapsis to 20 kilometers. Two of the three men would move into the lander, permitting it to follow the kind of descent profile already tested by the Luna flights. Solar cell deployment on the surface might support a one- to two-week stay. If resupply became necessary, platforms of the standardized type used in the Luna 15–23 series could be used for such logistics support. If the ascent vehicle failed to function when it was time to return to lunar orbit, it is even possible that a Luna launched by a D-class vehicle could carry a light-weight emer-

gency escape system. The United States considered a system which would have weighed about 700 kilograms, and this weight was less than the 840 kilograms landed on the Moon by Luna 21. This would require a transfer of propellant from the inoperative regular ascent vehicle to the emergency ascent vehicle. Obviously, it would not be easy to position the rescue ship with sufficient accuracy to permit the transfer of propellant.

Once return to lunar orbit was achieved, and docking with the orbiting habitat and heavy Zond accomplished, the crew would transfer into the heavy Zond, and cast loose the other two modules. The fuel in the torus tank of the heavy Zond would propel them toward Earth (TEI). On approach via the Antarctic, a skip reentry would be made by the command module over the Indian Ocean to cut G load, and on second reentry over Kazakhstan, this module would descend on its parachute to the surface.

Woods also suggests that in the summer of 1969, there may have been a last ditch attempt by the Russians to upstage Apollo 11. He suggested that perhaps the G–1–e first flight attempt which failed was carrying a 19,500 kilogram modified Proton converted to a laboratory, a 10,000 kilogram propulsion module, with a 105,500 kilogram propellant load to send the station toward lunar orbit. Then an A–2 might have launched a manned Zond to do an Earth orbit rendezvous with the lunar assembly before it was fired into translunar injection (TLI). That particular effort, if it was attempted, failed with the G–1–e failure.

But even though the race to be first to orbit the Moon or to land on the Moon was lost by the Russians, the subroutines of the Soviet effort continued for a time, such as the group flight and rendezvous of Soyuz 6, 7, and 8, which may have been simulating (unsuccessfully) the close formation and the assembly of a lunar spacecraft; propulsion module, lander/habitat, Zond (the Soyuz 6 tested welding techniques). Kosmos 379, 398, and 434 may have simulated full duration firings of the multiple start engines required for the lunar mission. The role of Kosmos 382 during the series is unclear since its delta V of 1,500 meters/sec does not relate to any specific lunar mission requirement. It will be noted again that Woods prefers a different interpretation of the four Kosmos flights from that proposed by Grahn, and implicitly selected by Kramer. Soyuz 9 ran the duration test in its 18 day flight.

Charles Vick is also working on calculations for possible Soviet manned lunar missions, and his numbers, also unpublished, are not yet down on paper in quite as complete form as the current Woods calculations, so that they are harder to assess. In general, however, he assumes a somewhat higher lifting capacity than Woods for the G–1–e as well as some stretch in the A–2, and in this way comes up with a smaller number of rendezvous operations which simplifies some parts of the mission. He sees the capacity of the G–1–e as 150,000 kilograms to Earth orbit and 70,000 kilograms to translunar injection (TLI). With this much lifting capacity, he would expect the Russians to make a pair of launches. One would be either a heavy Zond (8,029 kilograms) or a modified heavy Soyuz (8,936 or 9,843 kilograms) carrying a human crew; the other would be an all-up assembly of a lunar landing module (20,000 kilograms), a lightened Salyut (16,100

kilograms), and a service/propulsion module (20,700 kilograms) for a total weight in the range of 64,864 to 66,678 kilograms, within his estimated margin of the G–1–e. The Vick thesis calls for only two launches and two rendezvous operations: An all-up launch by the G–1–e to Earth orbit except for the manned Soyuz or Zond; one Earth orbit rendezvous to add the cosmonauts in their Soyuz or Zond; lunar orbit, with a lander going to the surface; and then one lunar orbit rendezvous after the surface stay, in order to prepare for the return to Earth in the heavy Zond or Soyuz. The contrast in simplicity is considerable by assuming a greater capacity for the two launch vehicles. If that capacity is not there, the Woods kind of approach with a larger number of rendezvous would be required. (Subsequent to the writing of this paragraph, Vick revised most of his numbers again, but essentially his approach is unchanged.)

f. Total Requirements for Soviet Manned Lunar Landing.—The foregoing pages have listed many of the major ingredients required for a complete and successful round trip by cosmonauts to the Moon. Soviet interest in such a mission has been evident from their own statements over many years. The appearance of many building blocks and many technologies and techniques also was accumulating the wherewithall in the latter part of the 1960's and early 1970's. Among the many suggestions of Western analysts, it is now possible to build scenarios as to how some of these basic building blocks might have been used to support such missions.

The real questions which remain probably revolve around questions of adequate materials, computational ability, quality control, reliability, and sufficient successful practice to make the inherent risks acceptable. This is where the real doubt lies. If the D–1–e vehicle had worked well consistently so that it could have been man-rated by 1968, and if the G–1–e vehicle had worked with the reliability of Saturn V, then the Russian timetable might not have been rewritten to put manned lunar landings on the back burner, so to speak. With four or five more years to think about this controversy since writing the 1966–1970 report, it still looks as if the Soviet interest in manned lunar landings in at least some parts of their space establishment was alive until the summer of 1969. It should be stressed, however, that the failures of the big launch vehicles to perform as hoped was not the sole stumbling block to successful missions to the Moon. Rather, these troubles were more broadly symptomatic of marginal performance in a number of aspects of Soviet space flight, which, considered in the context of the rigorous demands of the manned lunar mission, were crucial to success.

One of the most difficult tasks of making international comparisons of space programs is distinguishing between the essential and the refinements which bring the admiration of scientists or engineers. Even in the case of the American program with the passage of time one begins to forget the trauma of making systems studies and reliability estimates of the Apollo program. The late Dr. Nicholas Golovin associated with the staff of PSAC (President's Scientific Advisory Committee) was really convinced that the LOR approach adopted by NASA was so risky that if it were politically possible to keep making manned lunar attempts, some very large number of crews would be killed in multiple failures for each successful round trip. As one talks

with experienced American engineers and scientists who have come in contact with Soviet hardware and systems, it seems by informal survey that the majority consider the Soviet materiel and procedures quite inadequate by our standards.

Aviation Week did an extensive review of Soyuz before ASTP and more or less reached the conclusion that Soyuz was technologically less advanced than Gemini, let alone Apollo. Even if one accepts this as given, it still becomes necessary to recognize the Soviet program is an ongoing one that year after year is piling up more useful experience and more successes. As far as human safety is concerned, whether it is a matter of the small statistical sample, or a misinterpretation of what is essential, the Russian record on loss of human life is not essentially different from the American. Our three men burned up on the pad before they could even be launched. Their four men died in the terminal phases of two flights. But the near misses on both sides which managed to avert ultimate tragedy while bringing great credit to redundancy and human ingenuity are constant reminders of the narrow margins between survival and death. One thinks of the April 5, 1975 Anomaly in the Soyuz launch, the high spin of Gemini 8 and its Agena target and emergency landing off Okinawa, the explosion in Apollo 13 on the way to the Moon, the poisoning of the Apollo crew during recovery after the ASTP mission, the sinking of the Grissom Mercury capsule, and scores of lesser known events in both the U.S. and Soviet manned programs.

To bring this back to the Soviet manned lunar program: Some Western analysts flatly say no Soviet hardware has demonstrated the degree of refinement required to support lunar missions, and yet there have been successful Soviet unmanned flights of considerable challenge, including the Zonds, the several kinds of Luna flights, the operations to Venus, the long term operations of Salyut.

The conclusion of this section is that the Russians were serious about sending men to the Moon in flyby, in lunar orbit, and to the surface and return. They probably wanted to make the circumlunar flyby by November 1967, and slippage obsoleted the program by 1970. They may still have hoped to reach lunar orbit with men by 1969 or 1970, and this became out of the question as a result of the fly-by delays plus the G–1–e failure of 1969. Lunar landing, except for emptying the pipeline of test components, was set aside indefinitely in 1969.

This move to back burner (not abandonment) was not caused alone by the American successes or by the G–1–e failure. But the cumulative and interactive features of a successful Apollo program when coupled with Soviet inadequacies of reliable launch vehicles, and absence of a real indication that all the other necessary steps of computation, guidance, docking, could also be expected to be achieved with clear success before Apollo ran its course probably were sufficient to settle the matter in July or August of 1969. Probably there were some elements in the Soviet space hierarchy who saw what difficulties were coming well before that date, and there were others whose determination and enthusiasm continued past the official cutoff.

The question now is, will the Russians pick up the pieces and reapply their 1960's approach to manned lunar landing, making such flights any time in the next five years? Or will they await the coming of per-

manent orbital facilities, and later assemble the parts of a manned expedition to the Moon in Earth orbit, moving on a scale beyond that of Apollo, such as establishing a longer staytime in lunar orbit and a resupplied surface expedition? Both possibilities exist, but the former possibility of a renewed Soviet Apollo-type mission continues to recede with each year that passes without overt signs of the building blocks, the precursor analogs, and other clues that normally are the shadows cast ahead by major events.

In December 1974, there was some approach made to India about basing sea rescue forces there, reminiscent of the lunar Zond period, but such questions could be no more than a general contingency move related to emergency return from Earth orbit.

For the moment the conclusion is that a Soviet Apollo is not likely to appear in the next three years, but it might. The second conclusion is that for the longer run, the Soviet commitment to manned activities in deep space is sufficiently strong that within the decade there will probably be a Soviet landing on the Moon that will be a generation beyond the Apollo flights in the ambitiousness of the exploration goals.

7. Manned Planetary Flight

Having given considerable attention to the ephemeral manned lunar landing program, with the uncertainties as to when it will become substantial and then accomplished, it becomes less urgent to describe in detail how the Russians might conduct interplanetary flights.

The first question is, are the Russians interested in sending a manned expedition to the planets? The answer almost assuredly is positive; they are. In their public official statements, especially as quoted in the 1966–1970 report corresponding to this study, they named such manned flights as the prime ultimate goal of the Soviet space effort. Although the timetables are no longer realistic, there were statements that they would reach the surface of the Moon in the 1970 time frame, and would reach Mars before the end of the 1970's. Almost all these estimates, if not couched in specific years, moved the planetary events about ten years away, and hence with delays in the Moon program where many techniques might be proven and refined, the planetary operations also are receding.

There is something more to the Soviet plans than a vague desire, even though it is unlikely there is a firm timetable. One indication of possible interest is the long term effort to develop closed loop or partly closed loop life support systems. Men have been tested in an Earth-based simulated space ship for a full year with recycling of some of their logistic supplies of air and water. Both on the Earth and in space there has been serious work with chlorella and other ingredients of a closed ecological system. The heavy Soviet commitment of planetary explorer craft is consistent with doing the reconnaissance and testing which would precede manned visits.

Important, even vital, as long term reliability of space systems must be if cosmonauts are to be sent off to the planets on voyages that might last two to four years, also very significant is the appearance of a Soviet reusable shuttle to Earth orbit. If a shuttle were to become operational in the early 1980's, then an expedition to Mars might come by the end of that decade, and in any case if Soviet interest is sustained, before the turn of the century. The corresponding study to this

which covered the years 1966–1970 suggested the most likely manned planetary effort would be an expedition of 20 or so cosmonauts to Mars in the 1990's. Even with the current delay in manned lunar landings, that still seems possible.

Saunders Kramer saw a practice flight to Venus orbit, followed by landings on Mars. He suggested the minimum size expedition would be a payload of 450,000 kilograms and 10 men and women, with a more likely figure about 2,250,000 kilograms of payload and 30 men and women. He is a little more optimistic as to the timing, suggesting a date as early as 1986.[16]

The reason for stressing the importance of the space shuttle is evident if one considers use of conventional chemical expendable rockets as a logistics support for assembly of such an expedition. We know the D–1–e will put approximately 20,000 kilograms in Earth orbit or send about 4,600 kilograms toward Mars in a reasonably good launch year. To send a full scale Mars expedition with no waste for losses or for assembly costs would require about 489 launches of this vehicle. If each launch cost the equivalent of $50 million dollars, then launch costs alone would run about $24.5 billion.

In similar fashion, if the G–1–e vehicle were used and lifted 135 metric tons to Earth orbit or sent 31 metric tons to Mars, it would take perhaps 73 launches at the equivalent of $200 million each for a total cost in our terms of about $14.6 billion. This is still very steep for one country, since launch costs are only part of the story.

Suppose a space shuttle were used, whether American or Soviet. If the first generation American Shuttle carries about 25,000 kilograms to Earth orbit (with added staging to send 6,000 kilograms toward Mars), then it would take about 375 such launches at a minimum to put up a 2,250,000-kilogram expedition, and at $10 million a launch, that would come to about $3.75 billion. If a second generation Shuttle appears with both main stages reusable, as NASA once planned and as rumors say the Russians are developing, the costs change for the better. Then the cost to reach orbit is more like $5 million a flight, and the cost for a 2,250,000 kilogram expedition to be lifted to orbit is about $1.875 billion.

It should be emphasized that the cost to Earth orbit, while the greatest single logistics element, must still be supported by the cost of deep space escape stages, and all the paraphernalia of living quarters, power stations, landing and takeoff ships, and experiments, contained in the 2,250,000 kilograms of payload and maneuvering tugs and deep space propulsion.

Glushko and other Soviet authorities have mentioned that there is an important place for nuclear and for electric propulsion in any future manned expeditions to the planets, but with a space shuttle, even conventional chemical propulsion enters the realm of the feasible. One hesitates to put a figure on the out-of-pocket cost for mounting a Mars expedition, but if one assumes a program, whether American or Soviet, will already have other reasons to develop a reusable shuttle, a versatile space tug, and a universal space station module (all to serve many Earth orbital purposes of economic, military, and scientific purposes) then even the total costs of developing a Mars expedition

[16] Kramer, Saunders B. Soviet space activity, the next ten years, Spaceflight, London, July 1975, pp. 242–251.

become far different from the kind of $100 billion figure which has been common to the literature. People tend to overlook how much of the Apollo costs were associated with building a basic U.S. space capability rather than just going to the Moon per se. One might think of a Mars expedition of the type discussed as much closer to the order of magnitude of $10 billion rather than the $25–35 billion of Apollo or the $100 billion postulated so often for Mars. And these calculations accept the point made by Kramer that there would be little point in sending a small crew in a small ship to a destination as far away as Mars. While Apollo supported a crew of three sent toward the Moon with a weight of around 45 metric tons, this kind of Mars expedition with perhaps 30 members and 2,250 tons of ships and equipment would have a wide range of experiments, multiple landers, unmanned and manned, redundant quarters and equipment to enhance their survival on a voyage lasting years. The time span entailed is shaped not just by the months required to travel between the two planets, but the necessity to fly when the planets are positioned to make the flight in each direction compatible with both the weight of propellant required and the time for effecting the transfer orbits.

In summary, the Soviet lunar landing program probably lost its time table in 1969, but perhaps all the component parts were under development or actually flying so that with successful flight-testing a landing was not too remote. But so many ingredients have been missing from a manned planetary mission that no time table could be set realistically today. However, with the ultimate goal in mind, a sustained effort is under way to learn more about the near planets, and to master the techniques of sustaining human life in effective condition for the kind of long stay times required for planetary flight. If the propulsion elements described above do appear and work well, then a lead time of less than a decade might permit serious building of such an enterprise. Today, the trend seems to be toward thinking about international cooperation should such an expedition be considered. But no one can predict where space détente will be around 1990, and it is premature in the political and technical realities now to be talking specific plans.

8. Colonies on the Moon and Planets

Even the lay public as a result of exposure to "2001: A Space Odyssey" and "Space 1999" in movies and television are aware that the time will come when mankind will probably have lunar colonies. One of the best "documentaries" is a Soviet science film about lunar exploration and operation of future human cities on the Moon. The historical part of this film is non-political in that it gives reasonably balanced attention to both Soviet and U.S. exploration of the Moon, but the part dealing with the future cities seems to be exclusively Russian.

For the nearer term, the debate is between small scientific bases on the Moon versus a long-life manned station in lunar orbit which might send down occasional landers. It is possible that by the end of the twentieth century there will be on the Moon the equivalent of an Antarctic base. If so, the capital and operating costs will remain heavy for a period until the base can reach the point of being closer to self-sustaining by use of indigenous supplies.

It is too early to talk in concrete terms about permanent settlements on Mars or on satellites of the giant planets. If one were able to look

ahead the extrapolations in some cases would fall short of what some people predict, but other quite unexpected developments are quite possible. We have only to look at the surprises and rapid developments which have already come to human accomplishments which were not foreseen by any but perhaps a few dreamers. If propulsion breakthroughs in gaseous core nuclear reactors or in fusion power come along, transport costs could fall additional orders of magnitude, and travel time throughout the Solar System might fall from many months (and years) to only days. If ability to generate energy in useful forms continues to grow, men in future centuries may be able to "terraform" Mars, Venus, and some planetoids into useful and attractive places for human residence.

Such predictions have to assume that somehow mankind will avoid a world conflagration, deliberate or accidental, which potentially hangs over us with the growth in the power and number of nuclear weapons. Perhaps if some day the separate ambitions of national states and the problems of different ideologies should subside, the situation may become one of mankind as a whole struggling to sustain and enhance survival and the quality of life against the natural forces of the universe. Of course, nothing would be so calculated to close ranks than to have the international effort to detect and to contact extraterrestrial civilizations meet with success.

While the Russians might like to think of the Solar System becoming a Soviet lake and settlements on other celestial bodies allied with the Soviet system, this is far from a practical concern today, so long as there is not too great a disparity in the space capabilities of the Soviet Union and of other parts of the world.

9. Interstellar Travel

Talk of interstellar travel in both the Soviet Union and in the Western World is now limited to professional societies and individual scientists and engineers and is not a factor in governmental thinking.

It was not very long ago that eminent scientists were going on public record that ICBM's were impossible and that no rocket would ever reach the Moon. Although one can adopt premises which exclude the practical possibility of interstellar travel, thinking has already progressed to the point where there are ways of getting to other stars without breaking the laws of nature or waiting for magic space warps and teleportation. Interstellar travel will not be analyzed in the context of this study because of the early stage of thinking, but deserves brief mention because the thinking in both the Western World and the Soviet Union is being done, and in the decades ahead may reach the level of translation into policy issues.

C. PACE AND TIMING

It is far easier to describe with some confidence the directions and the content of the Soviet space program than to be accurate in gauging the timing of such events. We recognize in the performance to date a mixture of elements or qualities which almost seem contradictory. On the one hand, there are many Soviet forecasts and promises of what they plan to do, and yet delivery on these promises seems to come very slowly to the impatient outside observer. Soviet manned

flights during the period of the NASA Gemini and Apollo programs did not keep pace with the United States in number of flights or the level of achievement. Yet today they have an on-going program, unfolding fairly steadily, even though lacking for the moment its manned deep space elements. Even with this slow movement, the total level of Soviet activity is running higher than the U.S. program did at its peak in 1966. Obviously the Russians stay very busy, even though most of the activity no longer rates much mention in ordinary newspapers in the West, leaving the public unaware of this progress. Despite the prosaic nature of much of this activity by today's standards, the Russians are still capable of surprising the public in any year with bold new steps. Their authorities seem to relish these surprises and if asked when certain developments are likely to come the stock answer is "when we are ready", which is not of much help to the forecaster.

Sometimes the cycle of Soviet development seems faster than that in the United States, but in high technology this is not always the case. It almost seems the Soviet lack of depth in advanced materials, some aspects of propulsion, in computer capacity, perhaps in some other aspects of electronics stretches out development inordinately. The Soviet supersonic transport (SST) appeared very quickly after Concorde and seemed to borrow some of its design features, but introduction into revenue service has stretched out as has been true of the Concorde also. The fact the D class launch vehicle has not been used for a manned launch ten years after its introduction when it seemed a natural for such use, points to troubles. The G class vehicle already has gone close to eight years past the time it might have been expected to make a successful first flight, and the time is not remote when the project will be more than 15 years old since its probable inception.

Perhaps the important and enduring element is the seriousness and steadiness with which the Russians are adding to their space facilities and their space operations, building versatility and experience in depth. If they maintain the pace as they show every sign of doing, by the end of the century their space enterprises cannot help but be very formidable in the scientific, economic, and military sense. In the lifespan of nations this pace toward opening the Solar System and applying technology to gain the benefits of space is close to revolutionary.

The Soviet program is not a sham. It may be used from time to time for psychological and political purposes, but its real strength is the earnestness of the pursuit of long run capabilities.

D. SOVIET PHILOSOPHY TOWARD THEIR SPACE PROGRAM

A judgment on coming trends in the Soviet space program has to be cast not only in terms of engineering capabilities and prophecies, but in terms of the overall feel which one gains from reading and listening to Soviet statements about space activities over a period of time. This section offers a subjective judgment of the impression the Russians have created.

1. National Pride

The Russians in the past recognized their own shortcomings in economic and technological growth, and long have made a point of the

necessity to catch up and to surpass the most developed nations. Their successes in space have been a matter of great national pride to many segments of the population. And although over time, there is less excitement with further advances, the Russians know that they have demonstrated both to themselves as well as to the world that they need not take second place to anyone in a very broad field of modern science and technology when they can and have mounted one major space enterprise after another these past 18 years.

They have shaped their public information policies in ways to enhance this feeling of success, and have minimized disclosure of just how hard any nation must work to achieve good results and gain reliability on the demanding frontiers of advanced technology in the most hostile of operating environments. They do not deliberately reveal space failures, although some become evident anyway. But the advertised successes are real enough, and the pride which follows has been earned.

Accordingly, even though disenchantment eventually may set in to some degree, there is no early sign that this is sufficient to offset the positive benefits to the Russian spirit which have come from their space enterprises. Therefore, it is likely they will continue their heavy commitment to space work insofar as pride is a factor.

2. National Prestige

Soviet prestige has grown in the world as a result of their space successes. Other nations increasingly have looked to Moscow as a place to send graduate students and scholars for added training. Exports of Soviet industrial machinery, aircraft, locomotives, and scientific equipment have been enhanced and aided by the aura of quality and glamor rubbed off from supposed association with the Soviet space program. Although one does not know how to document it, the point has been argued that the flight of Sputnik 1 resulted in an increase of Soviet exports in excess of the cost of developing the Sputnik. Perhaps further space expenditures continue to be defrayed in part by such economic benefits.

The darker side of this new Soviet prestige is that a greater credibility has been afforded to Soviet claims of an invincible strategic rocket force for military purposes. In some past years, Soviet marshals as well as Khrushchev have been able to practice rocket diplomacy, threatening utter destruction to potential enemies, and drawing parallels between the accuracy of rockets hitting the Moon and the dropping of warheads on enemy targets at great distance.

Even if we have not progressed to the point of a nuclear and space standoff between the United States and the Soviet Union, to the extent that the space program continues to make the Soviet nuclear deterrent believable, as it does now, there will continue to be reason for the Russians to maintain their commitment to space.

The argument is made that the country which first conquers cancer or ends poverty will gain far greater prestige, particularly with the poorer nations of the world, than will any number of space flights which may be barely meaningful to the underdeveloped nations in terms of direct benefits which they might gain from space flight. The argument may be perfectly valid, but there is no sign that the Russians see the choice of whether to go into space as an either-or proposition.

Neither cancer nor poverty can be cured by government fiat, and there are other problems which also deserve attention and are not necessarily competitive with the space program.

Because the United States made a very costly effort to create its Apollo capability, which has it own problems of limited follow-on, it was no small Soviet achievement to acquire enough space prestige that they could become a partner in the Apollo-Soyuz Test Project. That exercise is seen by some Americans as a soft-headed U.S. give-away in the interest of détente, and by other Americans as a useful step toward future cooperation in which both sides gain.

3. The Engineering Logic of Developing Space Applications

The Soviet Government has at its many levels, including the highest, men whose professional training has been in engineering and science. The specialists from the space field can make their case for concrete benefits from space development and have some confidence that their arguments will be quickly understood, tested, and accepted in terms of engineering logic. There probably is less risk that appeals at the highest level will be judged in terms of more normative views or manipulated in relation to public works log-rolling or control of voting blocs. They also have a procedural advantage in that they probably do not have to fund projects on an annual budget basis, which risks continuity of work. They are more likely linked to five-year plans as the basic decision unit, and even longer term commitments can be made without the same threat of reversal with an early election. The political power in the U.S.S.R. is self-perpetuating in the sense that when new officials are to be elected, they are nominated by the people in power, and the vote is largely to ratify these decisions.

The Russian authorities have become convinced that use of space technology in support of work in meteorology, communications, navigation, and Earth resources is fully defensible in terms of the enhanced productivity of the national economy which will result. Even in the complete absence of national pride and prestige considerations, this work would still be well worth doing in terms of the economic benefits, some short term, others long term, and the investment is considered a wise use of capital.

One may argue whether a better engineering solution to Earth resources work lies in small, automated spacecraft or in large manned stations taking synoptic readings and bringing human judgment to bear in space rather than through remote controls on the ground. But this is a peripheral argument. Both approaches will work, and the decision becomes a broader systems problem which relates to total goals sought. The forecasts of practical applications to communications, weather, navigation, and Earth resources work in connection with space stations are almost always linked to plans for manned observatories looking outward and manned assembly stations to prepare ships for manned flight to the Moon and the planets.

Another area of space engineering applications is to military uses, and here, too, it seems clear that such work has been judged highly practical and immediate in the benefits returned. It is hard to imagine that the fragile world structure could have been held together through all the crises of recent years if the two major nuclear powers had not

had a de facto open skies policy to keep each extensively informed about the rate of weapons progress and military deployment through space observations. President Johnson made this abundantly clear in his famous Nashville speech of 1967, and Konstantinov, the Vice President of the Soviet Academy of Sciences, made an equally explicit statement to this effect in his visit to Yugoslavia in 1968. It is these necessary military support services flights which make up the year in and year out steady work of the major space programs.

For the future, there continue to be new opportunities to enhance the military usefulness of space all in ways which are non-aggressive and in complete accord with existing treaties limiting the military use of space. The Russians can be expected to continue to exploit these opportunities. Finally, both space powers are cautious or realistic enough to know that, short of universal disarmament, the greatest threats to stability in international affairs would come from some new imbalance resulting from a one-sided technical breakthrough in military weapons and strategy. Hence, the Russians can be expected to press vigorously on these frontiers as much in self protection as in seeking their own advantage to insure the strength of their position in the world. This spurs development, lest they be left behind.

Additionally, Soviet space technology has already included two military developments the United States has not undertaken: The Fractional Orbital Bombardment System (FOBS), and the Inspector/Destructor Satellite series. Whether there will be more threatening moves beyond mere military support flights remains to be seen. A spaceborne missile defense system is one potential application which is tied to future developments both in reusable space shuttle craft and in laser weapons. To date, this system has not become a reality, because the shuttle has not been built. Late in 1975, disclosures came that there was some evidence that ground-based lasers were probing U.S. military satellites in high orbit. An alternative explanation was that gas pipeline fires had been sensed. It is too early to assess this development with precision, but it could be the beginning of an ominous change destabilizing the previous relationship of live and let live in space.

4. Interest in Science and Discovery

The Russians have been practical in recognizing the political merits of a strong space program and most of their effort of recent years has been concentrated on applied tasks to support the national economy and especially to support their military services. But Russia for all its relative backwardness has a long tradition of interest in basic science, which has carried over into the Soviet state. The U.S.S.R. Academy of Sciences covers the range from practical to most basic research efforts, and this same spread is present in their space program. The Academy enjoys a special position of power which exceeds the more peripheral and advisory role of the U.S. National Academy of Sciences. Hence, we can expect that there will be continuing support for study of basic geophysical, solar, and cosmological phenomena in space, as well as study of biology and medicine. Lunar and planetary studies will probably continue to hold government support.

5. Willingness to Subordinate Immediate Consumer Gains

Although some of the choices between putting the national economic product to work for consumers and for various capital and public interest projects differ from country to country, often the variances are governed as much by the economic and material conditions as by publicised ideology. For example, the United States builds much of its philosophy and practice around supplying goods for private consumption, and looks to participative private ownership of the means of production through large corporations with widely-held stock. At the same time a large share of its total enterprise involves public financing of common services, including defense, welfare, provision of roads, and other public works. Also, many of the earnings of its private corporations are not paid out as dividends but are reinvested to further expansion of those enterprises. In Japan, the rate of reinvestment, as an alternative to direct private consumption, is very high indeed and accounts for much of the fueling of the remarkable Japanese economic growth machine both in advanced technology and in straight forward expansion. But even so, consumers in Japan have been close to universally equipped with color television sets, power washing machines, and refrigerators. Japan, like the United States, has also acquired a considerable amount of pollution and urban blight.

In the Soviet Union there has been an explicit subordination of consumer welfare in the present order to build "Communism"—very much what used to be scornfully called "pie in the sky" by Western labor agitators of an earlier age. Heavy industry has long enjoyed a priority over expansion of consumer goods and housing. When there are shortfalls in five-year plans, they have tended more often to be in consumer goals than they have been in heavy industry. At the same time, the lot of the Soviet consumer has been substantially improved over the 1930's, the World War II period, and the earlier postwar years. Consumers know they are better off, and most of them do not realize they are behind the improvements of their own client states in Eastern Europe. But if their expectations rise sufficiently, the previous pace of capital investment, including work in space, might be risked in some degree.

Philosophically, however, there may still be a willingness to recognize a certain amount of psychic income provided to individuals from community expenditures as well as from direct private consumption. Just as the poor peasant in some countries may take pride in beautiful cathedrals, the Russian on a waiting list for a washing machine, a refrigerator, or a car, may still gain some meaningful benefits from handsome rapid transit systems, from extravaganzas in Red Square on May Day, and from the prominent accounts in *Pravda* and *Izvestiya* or on color postage stamps that show how the Soviet Union is exploring the cosmos. Already accepting the concept of personal denial in the present for Communist pie-in-the-sky later on, the space program as a long term investment may have better luck in the Soviet Union than it will in a Western society that wants personal goods and services in the immediate present and whose economists apply ten percent discount rates to future benefits from space which make it "objectively" illogical to put capital into space systems that are the least bit imaginative or long term.

6. Marxist-Leninist Religion

The present regime of the Soviet Union is avowedly atheistic in philosophy, and traditional religions in that nation now do not have an easy time. Some people say that if God did not exist, he would have had to be invented. One can argue that when old deistic religions are out of favor in a nation, that the human spirit requires a secular religion. One form of such religion has been the personality cult unabashedly applied to dead leaders like Lenin, and from time to time to living persons as well.

On a more philosophical plane, the materialist view in present Soviet society (with a smattering of vocal dissenters who face considerable harassment) is that man is capable of controlling his fate and improving his well-being, using science as a major tool in his long run advancement. There is a recurring theme over the years that perfected Soviet man will triumph, and his seed and society will populate the Solar System. It may be that further exploration will demonstrate the difficulties of placing colonies on the Moon and the planets, but this point has not been reached. And if the faith in science is sufficiently deeply held, then we may find that despite difficulties the Russian people and government will persevere in their pursuit of a broad space program, expecting future discoveries in science and future improvements in power generation will permit them to do the necessary terraforming of planets, moons, and planetoids to make a fact of their colonization plans.

Hence opinions about Soviet intentions to explore the planets with men should not be judged alone in terms of American standards of early cost effectiveness and high financial risk, but be related to the almost religious overtones, and willingness to sacrifice to a degree the present generation in the interest of some very long term goals.

7. Final Conclusions

The Soviet space program remains a strong, on-going enterprise. One cannot be certain about the future of any program. But as of now, there is every indication of a continuing commitment to maintain a high level of activity and investment in a long-term orderly development of space science and technology, and its use in Earth orbit, at the Moon, and at the near planets now (and later the whole Solar System) for many purposes. This report does not prescribe an American response, which could include a mixture of reactions: Ignoring the Soviet actions and making our decisions on their individual merits; bowing out and leaving the field to the Russians; matching them in the competitive sense and working harder for primacy; or negotiating various accommodations, divisions, and cooperative ventures. If this report has supplied a description and an interpretation of the Soviet program, then the implications of these data and reactions of our policy makers still are to be determined.

CHAPTER SEVEN ANNEX

CHRONOLOGY OF SOVIET SPACE FORECASTS 1970–1975

By J. Glenwood Moore*

The report prepared for the Senate covering the years 1966 through 1970 inclusive contained on pages 359 through 384 a fairly detailed chronology which covered the time span of December 31, 1964 through December 29, 1970. This record is picked up in December 1970 and continued as far through 1975 as information is available, to gain whatever insights Soviet officials, scientists, engineers, and cosmonauts can provide through their statements on future goals and trends in the Soviet space program.

1970

The space museum in Moscow has put on public display an exhibit of a closed cycle life support system of the type intended for future manned voyages to the planets. (Aviatsiya i Kosmonavtika, Moscow, No. 12, 1970, pp. 33–34.)

1971

Engineer R. Borisov suggested that a future lunar mission might combine the efforts of two separate launches, one carrying a Lunokhod rover, and the other a sample returner, which landing in the same area could combine the kind of tasks performed by Luna 16 and 17. (Trud, Moscow, January 22, 1971, p. 4.)

The Chief Designer of Luna 17 forecast that advanced Lunokhods will far exceed the capacities of the first roving vehicle, being able to travel at night, travel at higher speed, and carry many more instruments. (TASS, February 6, 1971, 0542 GMT.)

The Chief Designer of Soviet Spaceships believed that it is very expedient to build in the near future in space near the Earth an orbital station that would operate a long time. Soyuz ferry craft are produced on a batch basis at the factory. (TASS, March 14, 1971, 0811 GMT.)

The Chief Designer of Soyuz spacecraft: "Of course, the time will come when people will certainly be setting out on journeys, say, to Mars. But first, they will accustom themselves fully and properly to circumterrestrial space and the Moon." (Socialist Industry, Moscow, March 14, 1971, p. 4.)

Academician G. Petrov and others stated that hundreds of thousands are involved in supporting the Soviet space effort. In the future, navigation and geodesy satellite systems will go into regular service, and other satellites will support the study of natural resources in fisheries, agriculture, water services, timbering, and geology. For these

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same purposes, use will be made of long term orbital manned stations. (Pravda, Moscow, March 30, 1971, p. 4.)

Corresponding Member T. M. Eneyev described in detail the energy requirements and advantages of flights which swing by the major planets as an economical way of reaching the outer planets. He also suggested that within 10 to 15 years, there will be nuclear powered rockets using hydrogen as a propellant, greatly aiding grand tours. (Vestnik Akademii Nauk SSR, Moscow, April 1971, pp. 13–21.)

Cosmonaut Shatalov: "The creation of orbital stations with replaceable crews is man's principal path into space. They can serve as space launching platforms for flights to other planets." (As well as serving practical Earth purposes.) (Aviatsiya i Kosmonavtika, Moscow, No. 4, 1971, pp. 1–2.)

Cosmonaut Yegorov discussed the relative places of men and automatic devices in space flight. "[Man] can, according to his own judgment, change the program and carry out more complex tasks, greater tasks than planned if he realizes they are feasible. Therefore we have not given up manned space flights, but I want to emphasize that where danger lurks for man or where he cannot safely pilot a spacecraft in view of the present level of technical development, there the work must be done by robots. You know that we are exploring the Moon, Venus, and Mars with automatic laboratories and we will explore other planets in the future by the same means." (Budapest Radio, April 6, 1971, 1645 GMT.)

Academician Boris Petrov: "The purposes of the Soviet space program are determined by the requirements of science and the national economy . . . The main trends as we visualize them today will probably be as follows: further investigations of near-Earth space, studying the Earth from space for purposes of space meteorology, geology, agriculture, oceanography, and marine and air navigation . . . Automatic devices are now being assigned the leading role in the exploration of space, the Moon, and other celestial bodies . . . In the present stage of the Soviet space program near-Earth space remains the main arena of manned flights . . . Over a relatively short period of time [Luna 16 and 17 proved it is possible] to obtain information on various parts of the lunar surface by launching automatic craft which are much cheaper than piloted spaceships." (TASS, April 8, 1971, 1830 GMT.)

Academician Boris Petrov predicted that small orbital platforms with several specialists may appear in the near future. They will exist from one month to one year. They will be replaced by large laboratories assembled in orbit, to operate for years, both in low orbit and at very great distances from Earth. (Radio Moscow, April 9, 1971, 1130 GMT.)

Academician Boris Petrov predicted that future Lunokhods will roam on the far side of the Moon with their data transmitted to lunar satellites intermediate to returning these data to Earth. He also predicted dual missions like Luna 16 and 17, with one flight delivering a Lunokhod to the Moon to roam and gather samples, and the second flight homing on the same landing site to remove a sample from the Lunokhod to return this sample to Earth. (TASS, April 12, 1971, 0627 GMT.)

Academician Boris Petrov predicted the next ten years would bring direct broadcast of television to home receivers, accurate short range

and long range weather forecasts, fast warning of disasters, aerospace and space transports to fly speedily between continents, further automatic exploration of the planets, laser communications, and more international cooperation in space. (Pravda, Moscow, April 12, 1971, p. 3.)

Cosmonaut Beregovoy predicted that within the next decade the problem of long stay time in stations will be solved, and a wholly reliable reusable space shuttle will be in operation. Cosmonaut Nikolayev predicted continuing orderly progress toward long term manned space stations, in which Cosmonaut Shatalov concurred. Cosmonaut Filipchenko predicted the creation of artificial gravity aboard spaceships. Cosmonaut Volynov saw more automatic exploratory ships to be followed by manned ships. Cosmonaut Sevastyanov saw the program changing from one of net outlay to strong economic gains in net balances. Additionally Filipchenko predicted a 1971 launch of a space station to be visited by successive crews. In summary, three of the six cosmonauts (Beregovoy, Nikolayev, and Shatalov) predicted a reusable manned shuttle in operational use within the next decade. (CTK report from Moscow, carried by Rude Pravo, Prague, April 13, 1971, p. 5.)

Academician Blagonravov again stressed the importance of manned flight. For example, he said that when several solar flares occur simultaneously, with odd and ill-defined forms, the data received by automatic instruments may not catch all of these within their field of vision, and only averaged data are provided. Men can exercise initiative and skill to develop a much more complete picture of what is happening. (Nedelya, Moscow, April 19–25, 1971, pp. 6–7.)

Cosmonaut Beregovoy predicted that in time there will be an international manned space station of enormous size which will fly in an extended orbit embracing the Earth and the Moon. Cosmonaut Shatalov predicted a joint international manned expedition to Mars. Cosmonaut Popovich expected the development of a rocket powered passenger craft to fly from Moscow to New York in half an hour. All three cosmonauts saw the next ten years bringing large permanently used space stations with rotating crews sent up in ferry craft doing Earth resources work, scientific observing, and space manufacturing. (Trud, Moscow, April 21, 1971, p. 3.)

Dr. Boris N. Petrov, chairman of the Interkosmos Council of the U.S.S.R. Academy of Sciences, remarked in Pravda that "the second decade (of Soviet space research) could be called an epoch of orbital stations, planned research work of men in conditions of space laboratories, a decade of wide use of automatic stations. Space exploration would progress toward gradually setting up simple—at first—orbital stations which would be followed by more complicated and bigger orbital stations for exploration, scientific and technical experiments. Universal research laboratories and specialized stations like astrophysical and radio-astronomical observatories, will probably appear. They may be either fully automatic or manned from time to time by a crew." He said that in the exploration of outer space, the leading role now belongs to unmanned vehicles. For the next few years they will remain practically the only instrument for the direct study of space and the planets. He noted that unmanned vehicles were cheaper than

manned ones, but stressed that the Soviet space program gives "a proper place to manned space flights" and that space vehicles and orbital stations will "often require the intellectual and creative activity of a man staying on board." *Flight International* concluded that Petrov probably meant that relatively short-term manned activities apply solely to the orbital station but that, in the long run, cosmonauts would be sent to the Moon and to Mars. (Flight International, London, April 22, 1971, p. 562.)

K. Ya. Kondratyev, U.S.S.R. Academy of Sciences Corresponding Member and Space Research Commission Deputy Chairman, reported that Soviet space research is developing in several completely independent directions. Meteorological, communications, navigational, and many other satellites make up the applied satellites area. Automated systems to study the Moon and distant planets form another area. Orbital scientific satellites constitute a third independent area. He said that in the important area of atmospheric pollution monitoring, satellites, and particularly manned spacecraft, can be very important. He said that some tasks are not possible with automated craft alone. He gave as an example observations of the Earth's crepuscular horizon. This, he reported, is the sort of work which was carried out on board Soyuz 5. (Komsomolskaya Pravda, Moscow, April 25, 1971, p. 1.)

Academician A. A. Blagonrovov explained the benefits of orbital space stations to Earth sciences. He said long-duration manned orbital stations, in combination with automated systems, will permit space research to be elevated to a qualitatively new level. Manned and unmanned systems will insure the uninterrupted and regular acquisition of scientific information in astronomy, astrophysics, and the biological sciences, and will help to set up the most complex scientific and technical, medical and biological experiments aimed at the further development of space research. Completely new opportunities are opening up in the study of Earth from space. Mentioned were: (1) research from space into the composition of the Earth's core; (2) the solution of such complex hydrological problems as the analysis of the moisture content in the soil, rainfall intensity, the presence of subterranean water, and so forth; (3) advancement in the science of surface and marine topography; (4) the detection of fish from space vehicles; and (5) continued study of the "terrestrial-solar" link to increase the reliability of long-range weather forecasts. (Pravda, Moscow, April 26, 1971, p. 2.)

Academician Blagonravov saw space stations as ideal for practical applications in the search for Earth minerals, moisture studies, oceanography studies (temperature, sea state, water color, currents), fish concentrations, magnetic surveys, and also work in radio astronomy. (TASS, April 26, 1971, 0546 GMT.)

Scientist Kirill Kondratyev said major results have already been obtained from space flights in meteorology, communications, geodesy, and navigation. He stressed the importance of manned observation as well as use of automatic devices for many further practical applications, both for resource management and for rapid reporting of threatening phenomena. (TASS, April 26, 1971, 1222 GMT.)

Academician Feodor Chukhrov detailed the future of space geology as a way of locating mineral resources, studying the structure of con-

tinents, measuring movements of the Earth's crust, mapping all changes on the surface of the Earth for constantly updated coverage, establishing a tightly controlled geodetic grid, and measuring the total thermal, radiational, and gravitational spectrum of the globe. (TASS, April 26, 1971, 1923 GMT.)

Academician Blagonravov saw manned stations as making a major contribution to studies of space physics, astronomy, astrophysics, and biological sciences. Stations will be the place in which new devices are tested, ultimately to permit the fitting out of manned expeditions to distant planets. He also stressed practical Earth applications. As an illustration, he said that photographs taken of Africa by the Zond 5 Moon flight built up a geobotanical map of that continent on the distribution of vegetation more accurate than data from hundreds of land expeditions over dozens of years. (Pravda, Moscow, April 26, 1971, p. 2.)

Academician Oleg Gasenko stated that orbital stations afford the best means of solving medical-biological problems connected with long stays in space, related to problems of readaptation to gravity after weightlessness, problems in the cardio-vascular system, and vestibulary problems. Also, he noted the psychological problems which may appear with extended flight, and the weakened protective reactions to micro-organisms. (TASS, April 27, 1971, 0746 GMT.)

Cosmonaut Nikolayev stressed the application of coming manned stations to atmospheric and ocean observation, pinpointing forest fires, tracing the movement of cyclones, prospecting for minerals, noting the ripening of crops, forecasting crop yields, and charting polar ice. He also saw a trend toward faster, larger capacity computers and reduced weights for instruments and other devices. (TASS, April 28, 1971, 0650 GMT.)

Cosmonaut Nikolayev reminded his readers that Leonid Brezhnev after the return of Soyus 6, 7, and 8 said "Our science has approached the creation of long period orbital stations and laboratories and these are the decisive means for the broad conquest of space. Soviet science regards the creation of orbital stations with replaceable crews as man's main path into space. They can become cosmodromes in space and jumping off points for flights to other planets. Major scientific laboratories for the research into space technology and biology, medicine and geophysics, astronomy and astrophysics will come into being." (Red Star, Moscow, April 28, 1971, p. 3.)

Cosmonaut Feoktistov said the primary emphasis of space development is becoming economic—crop control, oceanography, and geology, and also space manufacturing of super-pure crystals and metals. One of the most pressing problems is the reduction of costs of orbital flights by developing a reusable shuttle vehicle. Later will come manned interplanetary ships. (TASS, April 29, 1971, 0606 GMT.)

Academician M. V. Keldysh spoke of the possibilities of using space stations in the future as large scale power stations to transform solar energy to transmit it to Earth for use. K. Davydov reviewed the usual array of broad applications to be expected from future manned space stations. He further described as essential elements in orbital complexes (1) long term space stations, (2) transport shuttle systems, and (3) specialized modules and equipment to pursue research and to assemble

and launch interplanetary ships. He suggested that large stations will incorporate a nearby rotating facility to supply crews with recurrent exposure to the equivalent of gravity rather than rotating the main station which has disadvantages for some observations and also brings awkward coriolis effects. (Izvestiya, Moscow, June 9, 1971, p. 2.)

Academician A. Blagonravov reviewed the spreading importance of space flight to more and more nations, with over 1,000 successful launches, including about 500 by the U.S.S.R. He said in the last two years the Soviet Union had orbited about 1,600 metric tons of payload. He repeated the key role of manned stations for scientific research, for practical Earth applications, and for future use as launching pads for flights to other planets. (Red Star, Moscow, June 9, 1971, p. 2.)

Professor K. Davydov summarized the practical uses of manned stations for Earth resources work and for space manufacturing; also for developing solar energy for use on Earth, and as a launch platform for assembling interplanetary ships. (Isvestiya, Moscow, June 9, 1971, p. 2.)

Red Star promoted the idea that it would be cheaper to send a repair spaceship to a malfunctioning payload in orbit than to launch a replacement payload. It suggested that many of these repair missions could be launched from a manned station rather than direct from the surface of the Earth. Even with the best of systems, some missions both in Earth orbit and into deeper space will involve emergencies beyond the repair capacity of the crew, in which case there must be a capability to make a quick emergency launch of a powerful rocket carrier with a highly maneuverable rescue craft, supported by a wide network of ground tracking stations and command complexes. Red Star forecast that by 1990 there should be about 1 million man-made objects in orbit with a cumulative weight of 100,000 metric tons. This may require future sweeper spacecraft to collect and dispose of space debris. (TASS, June 19, 1971, 0809 GMT.)

Science correspondent Vladimir Denisov suggested that the Soyuz craft is the predecessor for future new space transports of greater versatility. Winged craft are probably coming which will land horizontally for recovery and reuse. This may take off either vertically or horizontally. Future rescue craft may be launched either from Earth or from space stations to do repair work. Their crews will have spacesuits and special portable devices for repair work either outside or inside other spacecraft. It is the feature of repeated use which will make these ships economical in promoting the conquest of outer space. (TASS, June 22, 1971, 1820 GMT.)

Academician Boris Petrov said that we can predict with confidence that the 1970's will be the epoch of development and broad use of manned orbital stations with changing crews, moving from occasional experiments in space to a regular vigil by scientists and experts in space stations. First will come more stations of the Salyut type, and then will come large and more complex multipurpose and specialized manned space stations. (TASS, July 4, 1971, 0706 GMT.)

Academician Boris Petrov predicted that another Salyut and Soyuz would be launched, and that the Soviet Union has not given up the plan to send men to the Moon in the future. He said it was technically possible for U.S. and Soviet spacecraft to dock together in the 1970's.

Despite the death of the three cosmonauts in Soyuz 11, he saw spacesuits as needed only for EVA work. The assembly of a large space station in orbit, a step beyond the docking of Soyuz and Salyut, is at the desk-discussion stage. (Paraphrased from a Moscow interviewer on July 30, 1971 with a Japanese correspondent.)

M. Ravich, doctor of geological and minerological sciences, said that it is difficult to overestimate the significance of space experiments for the study of inaccessible polar areas. Through the use of long-duration orbital stations and laser location techniques, it is possible to measure the drift of the mainlands with extreme precision, to locate their contemporary and ancient shorelines, and even determine the speed of the continents' movements. This, he said, will not only help in the reconstruction of the planet's geological past, but will open prospects for locating mineral deposits. If laser location from one board the orbital stations confirms that the Antarctic was once the nucleus of a single supercontinent—Gondwanaland, then geologists will be able with an adequate degree of certainty to identify the regions of Antarctica similar, for instance, to the diamond-bearing areas of South Africa. He said, too, that research into the polar areas from an orbit close to the Earth is also particularly interesting in that a survey from space gives a unique effect of "X-raying" the deep structures to a depth of several dozen meters. (Sotsialisticheskaya Industriya, Moscow, August 10, 1971, p. 3.)

Engineer S. Zhitomirskiy suggested that in the future, Venus may be more open to human exploration than Mars. He suggested that manned dirigibles in the atmosphere of Venus might operate in a temperature and pressure regime completely compatible with human survival without the pressure suit problems of the Moon or Mars, and that oxygen could be broken out of the carbon dioxide atmosphere. (Tekhnika-Molodezhi, Moscow, No. 9, 1971, p. 55.)

Cosmonaut Feoktistov predicted that future manned space stations will be more fully automated so that the crew can devote more time to scientific and economic applications of space than to spaceship housekeeping. Also, future stations will carry an even larger array of sensors and instruments than did the Salyut. (Izvestiya, Moscow, October 22, 1971, p. 3.)

Professor B. Rodiono stressed that manned space stations can be usefully employed both to relay urgent real-time data on current events in weather, agriculture, and fisheries, for example, and for long term data gathering such as geological studies, where it will suffice to bring back photographs on film. He also stressed the importance of synoptic measurements from many kinds of instrumentation. (TASS, October 26, 1971, 0022 GMT, quoting Pravda of that date.)

Engineer A. Vasilyev said scientists are now speculating on the possibility of spaceflights to Mercury. The first flight will probably be of a small payload in a fly-by mode to report on the atmosphere and to return photographs by facsimile. Design suggestions were offered. (Krylya Rodiny, Moscow, November 1971, pp. 28–29.)

Academician A. Blagonravov stated that Mars increasingly will be a main subject of research on the planets, including the search for life. The techniques coming into use are bringing an explosion in the amount of knowledge we can gain about Venus and Mars, contributing

to an understanding of the origins of the Earth. In the future men will go to Mars, perhaps about 10 men with logistics support in excess of 70 metric tons. But before men go, the way will be blazed by automatic ships, and much work will have to be done on improved rocket engines and on the maintenance of crew well-being in a small space for an extended period of time. (Socialist Industry, Moscow, December 11, 1971, p. 4.)

Academician Boris Petrov praised the new hardware used for Mars 2 and 3, and said that later equivalents of Luna 16 and 17 would provide hardware capable of roving over the surface of Mars and of returning actual samples of Mars soil to Earth. Despite the rapid progress in manned flight, he did not expect men to go to Mars during the course of the next ten years when only automatic devices will be used. (TASS, December 16, 1971, 1740 GMT.)

Academician A. A. Blagonravov commented on the significance and future of Mars probes. Higher capacity carrier rockets are going to be needed for planetary exploration. Manned expeditions to the planets such as Mars will best be assembled in Earth orbit, both because of the logistic support such flights will require, and the fuel needed for a round trip. In the near future, vehicles similar to Lunokhod will be sent to Mars to travel over the surface of Mars. Many difficulties lie ahead, but they will be overcome. (Pravda, Moscow, December 28, 1971, p. 3.)

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Academician Boris Petrov reviewed progress of 1971 in space flight. For the near future, he said emphasis would be placed in meeting the needs of science and the national economy. These include study of the properties of near-Earth space, and the physical origins and properties of the Moon, planets, and Sun. He listed again the applications of space technology to communications, meteorology, navigation, geodesy, agriculture, and mineral prospecting. (Selskaya Zhizn, Moscow, January 4, 1972.)

Yu. P. Kuznetsov, in discussing attempts to communicate with extraterrestrial civilizations, said at the present time there are communications of two types which are considered most suitable for interstellar communications: communications in one of the terrestrial languages (or the artificial language "lincos") and communications of the spatial images type. It is assumed that signals to extraterrestrial civilizations should be transmitted at frequencies from 100 to 10,000 MHz and accordingly received in the same range. The expected width of the signals spectrum is 10^5 to 10^{10} cps. He disagreed with the notion that signals of extraterrestrial civilizations can be detected using available radioastronomical systems. He said that existing equipment is capable of simultaneously determining only an extremely limited number of radioemission parameters. In seeking the signals of extraterrestrial civilizations it is necessary to have instrumentation capable of determining all important parameters of the signal simultaneously and to analyze them. (Zemlya i Vselennaya, Moscow, No. 1, 1972, pp. 30–33.)

Radio Moscow predicted that the present Molniya type communications satellite will be superseded by future models which give up solar cells for nuclear power sources. Powerful atomic reactors will raise power levels to the point that direct broadcast of television can

be achieved to individual receivers, instead of following the present practice of routing programs to an Orbita station prior to local distribution. (Moscow Radio, February 7, 1972, 0930 GMT.)

Academician Aleksandr Mikhaylov predicted that an automatic observatory on the Moon to conduct a wide range of experiments is quite conceivable in the not distant future. He said the same applied to Venus and Mars, and that the risks and costs of sending human crews to the planets exceed the value of such expeditions for many years to come. (TASS, February 29, 1972, 0655 GMT.)

V. Denisov, candidate of technical sciences, and V. Alimov, engineer, discussed possible practical tasks for automated lunar space stations which they considered feasible in the near future. An unmanned weather observation station could be established on the Moon to collect instantaneous weather data over the entire Earth. As a second task, radio and television programs transmitted from the Earth will be received by a lunar station and after being boosted, will be relayed back; terrestrial receivers will make lunar-boosted broadcasts available to millions of people. A third task would be to utilize the Moon as a convenient base for an automated astronomical observatory. An observatory could also be used to investigate cosmic rays, solar wind and corpuscular streams. A possibility related to this third task would be to utilize the Moon as one point in an Earth-based radiotelescope system. Research into celestial features is frequently performed simultaneously by two radiotelescopes located at a considerable distance from each other. A radiotelescope installed on the Moon and paired with a terrestrial one would have an effective distance on the order of 400,000 kilometers. As a result, the resolving power of the Earth-lunar complex increases significantly and it becomes possible to determine more accurately the structure of small terrestrial bodies very remote from the solar system. It was also noted that the Moon is free of terrestrial radio interference and that far longer uninterrupted observations would be possible than on Earth since the Moon rotates extremely slowly. (Sotsialisticheskaya Industriya, Moscow, March 22, 1972.)

V. B. Sokolov discussed space stations and interorbital transport vehicles of the future. It will be desirable that some types of orbital stations be assembled on Earth and put into orbit intact. In the future, however, stations of far greater size will be required than those which can be put into orbit by a single carrier-rocket. It will be necessary to develop transport ships and carrier-rockets which in full or part can be used more than once. In conducting some experiments there is a need for individual modules which are not rigidly attached to the stations. If the modules are close distance to the station the crew can service them without using special transport. If the module is distant from the station, it will be possible to use a transport platform with maneuvering by engine. Such "interorbital transport vehicles" may eventually be used to cruise between circumterrestrial and circumlunar stations and between bases on the lunar surface. As the number and size of orbital stations increases, some of them will be used as assembly-launching platforms where large interplanetary ships will be assembled from individual compartments delivered from Earth. (Zemlya i Vselennaya, Moscow, No. 3, 1972, pp. 14–19.)

Academician B. N. Petrov in discussing the Soviet space effort in the immediate future stated that man will not replace automated sys-

tems as explorers of celestial bodies until their possibilities have to a considerable extent been exhausted. He said that there is no basis for newspaper reports that men will fly to Mars in the 1970's. "In my opinion, Mars, not to mention the other planets, for many years will remain the object of investigation only by means of automatic vehicles." (Nedelya, Moscow, No. 16, April 10–16, 1972, p. 4.)

Cosmonaut Bykovskiy said that the main task of the Soviet space program now is to test thoroughly manned orbital space stations. Such stations will make it possible to implement a wide program of cosmic radiation research, observe the Sun and planets, prospect for minerals, conduct meteorological and make other investigations of importance to the national economy. He believes that in the future such stations will find application as orbital launching platforms for interplanetary spaceships on which it will be possible to assemble vehicles, refuel and test all their systems before starting a mission. Long-duration stations can also be used for training and acclimating cosmonauts before long space flights. He said that the current emphasis on space stations "does not mean that we are not at all interested in flights to the Moon or, say, to Mars. We shall make flights to the Moon and to Mars, and to other planets, but, as they say: all in due time." (TASS, Moscow, April 11, 1972, 1252 GMT.)

Cosmonaut Shatalov said that the Soviet Union is planning additional flights "probably this year." Specific dates were not announced in order to avoid criticism of the program if slippage occurred and to prevent unnecessary pressure on persons involved in the program. Concerning future lunar flights, he said that Soviet cosmonautics shall be working to improve its automated spacecraft. He said, too, that lunar flights shall continue and that missions in the future will be increasingly difficult. (Prague CTK International Service, April 11, 1972, 1723 GMT.)

Academician A. Blagonravov stated that it is now clear that man's space activity is not restricted to scientific research work alone. Space can constitute a raw material base for mankind. In the space environment it will be possible to carry out many manufacturing processes and celestial bodies themselves will become a source of valuable raw material. It is not impossible that in the future power plants will have to be stationed in orbit because they release heat into the Earth's atmosphere which can result in an unprecedented change in natural conditions. All this is in the distant future and will become a reality only with improvements in space technology. (Pravda Ukrainy, Kiev, April 12, 1972, p. 4.)

Cosmonaut Shatalov stated that Soviet cosmonautics has set as one of its main objectives the development of durable orbital space stations through which a whole range of research and national economic tasks could be resolved. Some of the possibilities he cited were to utilize space systems to track meteorological processes, warn people of imminent danger promptly, prospect for useful minerals, determine the condition of crops, spot regions rich in plankton and, therefore in fish, and locate the centers of forest fires. When larger long-duration orbital stations than are now available appear, highly trained scientists will work alongside the cosmonaut. It was his view, however, that no matter how much the staff of orbital stations may increase,

cosmonauts will still have to be quite versatile and be able to substitute for each other so that the main crew can perform the scientists' functions and the scientific personnel can control the spacecraft. In the future, he said that it is indisputable that stationary laboratories will appear on the Moon and expeditions will head for Mars. It is quite possible that the personnel of such lunar stations and the crews of the Martian ships will be international. At the present stage of the Soviet space program, however, automated spacecraft will play an enormous role in the study of the Moon and the planets of the solar system. (Izvestiya, Moscow, April 12, 1972, pp. 1–3.)

Academician Šedov: "Automatic vehicles have now many times convincingly proved their capabilities as a sole means of exploring circumterrestrial space, the Moon, and the planets in the initial stages." Concerning manned missions to the planets, he said that a landing on the Venerian surface by a manned spacecraft is impossible, at least within the foreseeable future. Moreover, in general terms a manned mission to either Venus or Mars is an unusually complex and expensive task, immeasurably more problematical than sending a man to the Moon. He was confident that the problems of manned exploratory missions to the planets would be solved, but for a long time to come scientists will be receiving their main information on the planets from unmanned craft. He said that in the next few years it is entirely possible that long-duration space stations with international crews will appear in circumterrestrial orbit. Debate, he said, has been in progress for some time on a draft plan to organize an international manned scientific laboratory-station on the Moon. (Krasnaya Zvezda, Moscow, April 12, 1972, p. 2.)

K. Ya. Kondratyev, U.S.S.R. Academy of Sciences corresponding member, said that a combination of space and Earth-based technology offers extremely great possibilities for learning about the Earth's environment and natural resources. He cited as examples the prospects for using remote space-based sensing systems in combination with direct measuring Earth-based systems to: (1) Develop models for fishing in the world ocean. (2) Provide uninterrupted weather data collection. Soviet weather satellites also carry actinometric instruments which permit a study of planetary distribution of heat absorption and radiation. And (3), map the Earth's surface. He said, too, that certain tasks exist which can most effectively be resolved only with spacecraft manned with crews which include specialists trained to fulfill an appropriate scientific program. The need for long cycles of uninterrupted and comprehensive observations makes it essential to develop long-duration manned orbital stations which become bases for research into the planet's environment and natural resources. (Sovetskaya Rossiya, Moscow, April 19, 1972, p. 3.)

Cosmonaut Ye. Khrunov discussed the problem of eliminating or attenuating the adverse effect of weightlessness on the human body caused by long-duration orbital station operations. The most effective means for contending with the undesirable effects of prolonged weightlessness would be the creation of artificial gravity. However, its creation would involve great difficulties. For this reason scientists are seeking other ways to extend the time man spends in space. Proposals include the wearing of anti-G suits and use of special trainers, vacuum

and other devices. A special work and rest schedule has been developed, together with physical exercise programs. Different kinds of drugs are being tested. (Pod Znamenem Lininizma, Moscow, No. 5, 1972, pp. 47–49.)

B. Kozlov described the future Martian automatic rover. In establishing communications with a future automatic Martian rover it would be better for data to be relayed to a Martian artificial satellite which would then transmit accumulated data to Earth. Effective data collection under such conditions necessitates the development of cybernetic systems working with special electronic computers capable of controlling the course of scientific investigations. In order to 'see' potentially hazardous obstacles, or anything of interest, the vehicle may carry an emitter which in conjunction with an optical system will illuminate with a vertical ray the terrain in front of the vehicle for several tens of meters. On both sides of this light source there will be television cameras forming a stereoscopic system. Illuminated points will be viewed through special light filters. Video signals from both cameras will be processed by the on-board computer. The vehicle will thereby receive complete data on local relief. If an emergency situation arises, the computer will cut out the engine and at the time of the next communications contact will describe the circumstances and await orders on how to rectify the situation. A special system, such as that developed for the "Mars 3", must be provided to boil down accumulated data prior to its transmission to Earth. (Radio, Moscow, No. 7, 1972, pp. 16–18.)

Professor G. A. Gurzadyan said that the launching of a telescope with a mirror diameter from 1 to 2 meters into Earth orbit can be expected soon. One possibility for exoatmospheric astronomy would be to establish an observatory in stationary Earth orbit. Still more promising would be the creation of such an observatory on the Moon. He said at present the objective is to develop automated observatories, rather than those operated by man. However, when large space stations are established it will be entirely feasible for astronomical observations to be made with man's direct participation. It has been calculated that a telescope with a mirror with a diameter of 1 m operating in space would be more effective than a telescope with a mirror of 10-m diameter operating at the Earth's surface, and the latter will probably never be constructed due to the great technical difficulties and enormous cost. He said that for this and other reasons, the future clearly belongs to exoatmospheric astronomy. (Abstract: "Telescopes are ready for launching," interview with Professor G. A. Gurzadyan. Nauka i Teknika, Riga, No. 9, 1972, pp. 13–16.)

Cosmonaut Shatalov expressed the hope that the manned flight to Mars, which will probably be made before the end of the twentieth century, will be an international flight—possibly a Soviet-American flight. He said that as space exploration becomes more complex and more costly, it is necessary that the efforts of nations should be pooled. As evidence that international cooperation has already begun, he briefly discussed joint programs with the German Democratic Republic (GDR), Czechoslovakia and other socialist states, as well as Soviet-French and Soviet-United States arrangements. (Moscow, TASS, October 1, 1972, 1745 GMT.)

Pilot-cosmonaut K. P. Feoktistov expressed his belief that the Soviet space program will not only cover its own expenses but will also

yield large profits. He cited space communications systems, and meteorological and navigation satellites as examples of space technology that are already beginning to pay for themselves. He was confident that in the future it will be possible to influence certain natural phenomena, such as weather modification, through space technology. The study of the Earth from space will yield data to advance our understanding of the origins and evolution of the planet. He did not believe that the exploitation of other planets' natural resources for terrestrial needs would begin in this century. Manned missions to other stars are out of the question. He said that much has been written about the use of photon engines on flights to the stars, but at present these engines do not exist, although they will be built. (Komsomolskaya Pravda, Moscow, October 4, 1972, pp. 1-2.)

Cosmonaut Sevast'yanov on the importance of satellites: "A cosmonaut can visually scan and photograph our planet for studying processes which are developing with particular rapidity. Study of the spatial structure of clouds will assist in predicting the weather and increasing the reliability of forecasts. Orbital stations and spaceships will help in solving hydrological problems and in preventing catastrophes associated with droughts and floods. Cosmonauts in circumterrestrial orbits are able to study frozen and unfrozen water bodies, the extent and depth of snow cover and changes in water levels in rivers and to predict periods of high and low water. Such forecasts are needed for the proper operation of hydroengineering systems and for draining and irrigating lands. Observations from space will make it possible to compile maps of currents in the ocean, which are so important in determining meteorological conditions in different parts of the Earth. Space photography is of exceptional value in the quest for mineral deposits, in studying the nature and intensity of recent tectonic and physiographic processes. Such investigations will help in ascertaining the laws of formation of geological structures determining the distribution of petroleum, gas and other minerals. Geographers can study different types of terrestrial features, including bottom relief of the world ocean. The face of our planet is constantly changing under the influence of natural forces and human activity. Present-day maps are some years out-of-date. Space observations will make possible rapid map revision. Agriculture will be aided by cosmonautics. On the basis of space observations of fields on different continents and analysis of soil erosion it will be possible to formulate recommendations on the proper use of new lands." (Pravda, Moscow, October 4, 1972, p. 3.)

Cosmonaut Shatalov discussed the increasing importance of cooperative space activity in international relations. He said that while the landing of the crews of the "Apollo" ships on the Moon was a great achievement of the American people; it required enormous expenditures. Expeditions to distant planets will involve a still greater expenditure of energies and monies. He said that he would like to believe that under conditions of mutual understanding and peace among peoples, such activities as manned flight to Mars, which may possibly take place prior to the end of the 20th century, will become international. He said that possibly it will be Soviet-American. (Interview with TASS correspondent Yu. Shevyakov. Leningradskaya Pravda, Leningrad, October 4, 1972, p. 3.)

Academician Glushko predicts that rockets of the future can be lifted into interplanetary space by a complex of engines consisting of liquid-fueled rocket engines, nuclear engines and electric engines. The launching and flight of such rockets will be as follows: on the launch pad chemical-fueled engines are fired, and then, when the carrier-rocket puts the ship beyond the dense layers of the atmosphere, nuclear rocket engines will be used. Finally, low-thrust rocket engines will be used to impart enormous velocities to a spaceship over great distances. Such carrier-rockets will be in extensive use by the end of the 1970's. The time will soon come when carrier-rockets will be used in flying to different points on the Earth's surface over flight distances of 10,000 to 15,000 to 20,000 km. (Abstract: "Commentary by V. P. Glushko, Soviet space, expert on his life and times," interview between A. Romanov (TASS) and Academician V. P. Glushko. Moskovskiy Komsomolets, Moscow, October 14, 1972, page unknown.)

Academician L. Sedov: "I think that the time will come when the flow of goods and passengers along the 'Earth-space-Earth' route will increase substantially. Such mass transportation will require a new form of space transport—aerospace systems that can be used repeatedly. These 'space shuttles' represent a combination of a booster rocket and an orbital aircraft capable of landing at airfields on Earth. The development of such a system is a matter for the future." (Izvestiya, Moscow, October 17, 1972, p. 5.)

Cosmonaut Shatalov said that the exploration of space by both manned and unmanned spacecraft is to continue, in the future, each program supplementing and developing the other. He predicted a great future for large orbital stations equipped with supergigantic telescopes. He also predicted that huge cosmic reflectors one kilometer square would be put into near-Earth orbit to concentrate and direct solar radiation to selected areas on the Earth's for the purpose of climate control. He predicted that after large manned space stations have been perfected, it will be possible to put large power stations into orbit to convert solar energy and transmit it back to Earth in the form of powerful radiation (microwave) which in its turn can be converted into electrical energy. He said that the Soviet space program is becoming an increasingly important integral part of international relations. (Moscow, TASS, November 4, 1972, 0955 GMT.)

I. Merkulov, Deputy Chairman of the Cosmonautics Committee DOSAAF, said that ion engines have not yet been perfected. Electric rocket engines require a source of electric energy such as an on-board atomic power station or solar cells. Present-day space atomic power stations have a considerable weight disadvantage. Besides this, ion rocket engines can develop a thrust which is extremely small in comparison with their weight and therefore are capable of imparting only an extremely small acceleration to a space vehicle. He said that all of this makes the possibilities of their use on space vehicles highly complex. (Aviatsiya i Kosmonavtika, Moscow, No. 12, 1972, pp. 38–39.)

1973

Cosmonauts Filipchenko and Kubasov and Professor Dr. Mikhailov, director of the astrophysical observatory in Pulkovo, were interviewed during the International Astronautical Federation Congress

in Vienna in September 1972. In response to a question about Soviet space goals through the year 2000, it was agreed that the Moon, Mars, Venus, and probably in several years, Mercury and the outer planets will be the objects of unmanned space probes. At a later time after the possibilities for automated craft have been exhausted, and when the time has come to establish permanent stations on the Moon, Soviet cosmonauts will also land on the Moon's surface. Four to six years may possibly pass until that time. Manned flight to neighboring planets lies in the even more distant future. Manned Mars expeditions could be expected toward the end of this century. Since the costs of such an expedition are very high, such a flight would actually be feasible only through international cost sharing. Because of its extreme temperature and pressure conditions, the planet Venus may be completely out of the question for a long time. The major problem in extended space flights continues to be weightlessness. According to present scientific knowledge, an interplanetary expedition which did not create its own artificial gravity would hardly be possible. (Flieger-Revue, East Berlin, January 1973, pp. 20–21.)

Academician A. A. Blagonravov said that around 30 Soviet lunar missions have been launched so far and that researchers consider additional lunar missions important. He described the Moon as a long-term orbital station where scientific instruments delivered by automatic and manned spacecraft operate for long periods. The use of a standardized landing stage is economical and it makes possible the sending of a variety of payloads to practically any spot on the lunar surface. He stated that mobile automated systems provide an excellent means for obtaining detailed information needed to answer the remaining questions the Russians have about the Moon. Automated Lunokhod-type vehicles will also be important to the study of Mars and other planets. Because of the great distance between Earth and Mars, and the consequent time-lag in the transmission of commands, it will be difficult to make the vehicle autonomous. Continuous control of motion is inconceivable. He said there is no doubt that in the near future the first Mars rovers will be transmitting information from the surface of the planet. Prototypes of Martian rovers, he said, are being tested and perfected on the Moon. Concerning the respective roles of man and machine in the study of space, he said that automated spacecraft will always precede manned missions although they cannot replace man in everything. He said that the exploration of the Moon and the planets with automated systems is the most rational approach at the moment. Recent research indicates that manned flights to Venus, Jupiter, Uranus and Neptune are totally out of the question. Consequently, the way is open only to automated vehicles. (Pravda, Moscow, March 19, 1973, p. 2.)

Cosmonaut Shatalov stated that many space research tasks can be accomplished only through prolonged manned missions. He said that future plans for space research are tied to the development of heavy artificial Earth satellites, such as the Salyut orbital station. The plans give rise to the problems of long-duration orbital space stations and reusable spaceships which he believes the space industry will be able to solve. Central to the manned-flight program is the effort to develop long-duration orbital stations. Progress in interplanetary exploration will be made through the conquest of circumterrestrial space, includ-

ing the Moon. Orbital stations, he said, will become cosmodromes for the assembly of interplanetary ships and the equipping of expeditions for outer space, as well as for training and acclimating cosmonauts. (TASS, Moscow, April 18, 1973, 1532 GMT.)

Cosmonaut N. Rukavishnikov stated that it is not unrealistic to expect a manned flight to Mars. Most of the difficulties are associated with the length of time required for the mission. He noted that there are a great many trajectory variants and the choice of a particular one will be dependent on the conditions which must be ensured. Scientists are attempting to develop a closed ecological cycle for solving the problem of the requirement for a 1½ year supply of food, oxygen and water. (Kazakhstanskaya Pravda, Alma-Ata, April 29, 1973, p. 3.)

M. Kaplanov reported that the Soviet Union is now developing technology which will make it possible for television viewers to receive signals directly from satellites. He noted that a decisive condition for the development of such a system of direct television broadcasting (DTS) is to increase some hundreds of times the strength of the signal emitted by the satellite-based transmitter. The satellite's power unit must have a capacity equivalent to tens of kilowatts. [At the time the article was written, the "Molniya-1" satellite was the most powerful space transmitter and it had a power of 40 watts.] Other possibilities for space communications satellites were mentioned: transmission of data to automated control systems; increased safety of air and sea traffic through improved reliability of communications in remote areas; and establishment of space information centers for gathering and recording information from other space apparatuses for the purpose of instantaneous data transmission. (Izvestiya, Moscow, May 6, 1973, p. 3.)

Cosmonauts Leonov and Kubasov stated in an interview that despite the Soyuz 11 accident, the Soviet Union is not developing a new spacecraft. Certain detailed changes and improvements will be made, however, and instead of three cosmonauts, there will only be two who thus will be able to wear spacesuits. Concerning manned flights to the planets, Kubasov said that such flights may be attempted perhaps after some very complicated technical problems are resolved, but in any case, in no less than 10 years. Leonov said perhaps they would land on Mars in 1980 or 1982. Leonov stated that the successful lunar investigations with automated spacecraft do not rule out manned flights. He said the Russians are working toward this, but the present program is based primarily on launching very heavy orbital stations. (L'Humanite, Paris, May 28, 1973, p. 14.)

Professor Konstantin Bushuyev, the director of Russian work on the Apollo-Soyuz Test Project (ASTP), stated that the 1975 ASTP flight is only a beginning in Soviet-American cooperation in space. He considers the space rescue capability, which the ASTP mission would test, although important, is just one aspect of the program. In a separate interview, Major General Shatalov, head of cosmonaut training, expressed the hope that the 1975 flight will not be the last joint operation with the United States. (Flight International, London, June 21, 1973, p. 966.)

Georgiy Petrov, director of the Institute of Space Research, U.S.S.R. Academy of Sciences, highlighted Soviet accomplishments in the use

of space technology to investigate the Earth's magnetosphere, very high energy cosmic rays, the Moon, Mars, and Venus. In the future, weather satellites will provide the information necessary to influence the weather; radio-astronomical observatories in space will yield information on the most remote regions of the universe; and, he predicted, the time is near when satellite systems will be built in the Soviet Union to solve a broad range of problems concerning the economic activities of man and the study of the planet Earth. (Space World, Amherst, Wisc., June 1973, p. 23–24.)

In a radio broadcast it was reported that multi-use, reusable space transportation systems are being developed in several countries, including the Soviet Union. A two-stage vehicle with both stages piloted, was described, but not attributed to any country. (Moscow Radio in German to Germany, July 2, 1973, 1812 GMT.)

Academician Glushko (developer of liquid-propellant rocket engines in the U.S.S.R.) was reported as saying that environmental protection will require that in the future it will be necessary to place nuclear and thermonuclear power plants and certain industrial operations outside the Earth's atmosphere. He said that scientists and engineers in many countries are now working on the problem of establishing mining and processing industries on the planets. He believes that it will be possible to build automated manufacturing systems on celestial bodies closest to the Earth which would produce semi-finished and even finished products. The manufacture of goods in space has already begun. He stated that while the orbital station "Salyut" was launched for the purpose of research, in the future it will also have production purposes. He sees stations such as the "Salyut" as a forerunner of space cities with all the features typical of cities on the Earth. (TASS, Moscow, July 30, 1973, 1614 GMT.)

N. Mikhaylov stated in an article excerpted in *Moskovskaya Pravda* that the Russians are conducting searches for extraterrestrial civilizations. Recently, 12 stars located between 10 and 60 light-years from the Earth were subjected to careful study under the direction of Corresponding Member of the U.S.S.R. Academy of Sciences, V. S. Troitskiy. The study was conducted at a wavelength of around 30 cm. In a simultaneous program observations were made at 50, 30, and 16 cm wavelengths at Gor'kiy, Murmansk, Ussuriysk and in the Crimea. Scientists have not as yet succeeded in detecting signals but the experiments are continuing. (Excerpts: "Reply, Aelita," by N. Mikhaylov. Moskovskaya Pravda, Moscow, October 7, 1973, p. 4.)

Academician Valentin Glushko stated that there is no engine to replace the liquid-fuel rocket engine in the foreseeable future. Nuclear engines are unsuitable for taking off and landing because of radioactive contamination; ion engines, because of their small thrust, can only be used after the rocket has reached escape velocity. In the rocket of the future, he said it seems reasonable to utilize liquid-fuel engines and, in individual instances, solid-fuel jet engines in all take-off and and landing stages. Nuclear engines would be used to take the rocket to orbital or even escape velocity. Finally, the ion engine would be used when escape velocity has been reached. "A rational combination of engines of this type will be able to meet cosmonautics' transportation requirements for a long time to come." (Leningradskaya Pravda, Leningrad, October 11, 1973, p. 4L.)

In an article by A. Donets and D. Pipko it was reported that the space shuttle concept was presented at the 24th International Astronautical Congress held in Baku as a possible solution to the problem of reducing the cost of space launches. The United States space shuttle was described. (Sotsialisticheskaya Industriya, Moscow, November 18, 1973, p. 4.)

K. Kondrat'yev, Corresponding Member of the U.S.S.R. Academy of Sciences, said that only through satellite coverage can reliable data on the environment be obtained which would insure that the theoretical arguments on environmental degradation assume a truly scientific nature. While remote space sensing makes it possible even now to resolve a number of practical Earth-related problems, he said that much still has to be done to improve and develop the technology. The tasks he mentioned included improving the accuracy in interpreting satellite information; continued research on the comparative analysis of images of different scales; expanded non-meteorological interpretation of satellite meteorological information; and continued research on the problem of combined subsatellite geophysical experiments with the aim of improving methods for the clear interpretation of the data. He also mentioned the need to compare in detail the potential of manned orbital stations and automatic satellites and to study the possibility of using the Moon as a platform for remote sensing of the parameters of the Earth and its atmosphere. (Pravda, Moscow, December 25, 1973, p. 4.)

It was reported that the Soviet Union has developed a lunar roving vehicle which can walk across the surface of the Moon on six "legs" at a speed of 6 kmh, according to TASS. The spider, built by the Leningrad Institute of Aviation, is remotely controlled by means of a laser beam, which apparently can also be used to transmit data back to the control center. (Flight International, London, December 27, 1973, p. 1062.)

Correspondent: Unlike the space transporter being planned in the United States, the Soviet transporter is to be first used for long-distance flights on Earth; later it will be used for routine journeys between space and Earth. An "airport machine" will carry the space glider "piggyback", lift it to an altitude of 30 km after a horizontal takeoff, and then return to its point of departure. At the 30 km altitude, the space glider will ignite its rocket engines, rise to an altitude of 100 km, and achieve an orbiting speed of 28,000 km per hour. The space glider is intended to have the capability of flying to any point on the Earth with passengers or freight on board and land like an aircraft. The first practical flights are to take place at the end of the 1970's or the beginning of the 1980's. In the second planning phase, the space glider is to be developed into a commercial means of transport operating between Earth and space with the capability of being able to withstand up to 300 flights into space without incurring damage. (Complete text: [FRG Magazine on Plans for Soviet Space Transporter], Hamburg DPA Radio in German, December 29, 1973.)

1974

A. Serov discussed the scientific and technical problems that need to be solved before a manned Martian expedition can be attempted.

The conclusion is drawn that it is feasible to begin serious designing of a manned Martian complex only after the accumulation, first, of a great amount of information concerning Mars using unmanned Martian rover vehicles, and second, the accumulation of sufficiently encouraging data concerning the long-term presence of cosmonauts aboard a circumterrestrial station. In short, such work could be carried out somewhere at the end of the 1970's. Moreover, 10 years are needed for designing the ship and the equipment for its delivery into circumterrestrial orbit, their construction and ground tests, etc. And thus the most optimistic prediction for a manned Martian expedition is the 1990's. It was stated, too, that it is extremely desirable that the problem of manned flight to Mars should "mature" before it is undertaken seriously. (Sovetskaya Estoniya, Tallin, April 11, 1974, No. 85 (9266), p. 3.)

Cosmonaut Shatalov said that Soviet cosmonautics is directing all its efforts to creation of long-duration orbital stations. He believes that before very long there will be a great many stations having different functions which will operate continuously in Earth orbit. Before this will occur, however, a transport ship must be developed which will make so-called shuttle flights from the Earth to orbit and back. He views this development as the key to solving the entire problem of expanded use of space. Designers do not have a shuttle but they are continuing the search. He extolled the space effort and cited specific advantages and meaningful results, including: live television coverage of international events; the cost-effectiveness of meteorological satellites; the possibilities for giant telescopes in space; the possibility of creating a giant reflector in orbit—a sort of artificial sun—to influence the weather; communications with any point on Earth; and atomic electric power stations in space. He considers international cooperation an important step in space conquest because it becomes possible to use the best that prevails in each country. In response to a question about planned manned flights to other planets he said, "At present we are not discussing any specific program which would provide for landing of a man on the Moon, Mars or elsewhere. We feel that the information which is furnished us by automatic vehicles, on the one hand, will suffice for science today. . . . On the other hand, these data are inadequate for seriously thinking about preparations for an expedition, for example, to Mars." (Sovetskaya Rossiya, Moscow, April 12, 1974, p. 2.)

Cosmonaut Shatalov in commenting on the relative roles of man and machine in space, said that if man does fly to Mars, it would be highly effective if man and machine were combined, since this would obviously yield far more valuable information. Not only would data be collected, but the crew would routinely evaluate it on the spot and the most interesting data would be further developed. In the case of great distances which man cannot yet travel, the solution of special problems will be by the use of automated systems for the time being. He said that when laser communications are established between the Earth and its satellites, there will be essentially unlimited possibilities for television transmissions and telephonic conversations on a planetary scale. He also praised other applications satellites and the collaborative space efforts of other socialist countries and France. (Gudok, Moscow, April 12, 1974, p. 4.)

Cosmonaut Shatalov said that the space program has three specific directions: The first is thorough, multisided investigations of circumterrestrial space and the planet Earth itself. The second is studies directed to further improvement of space apparatus designed for investigations in circumterrestrial orbits, in distant space and on other celestial bodies. The third is experiments of an applied nature associated with the broad use of space for the national economy and culture. Extremely significant results have been attained in each of these directions. Manned stations in Earth orbit are of enormous importance in solving scientific and practical problems. He said orbital stations have a great future. With respect to such stations and the transport ships which will cruise between them and the Earth, it is necessary to solve primarily the problem of increasing the profitability of rocket-space apparatus. It is necessary to increase significantly the useful life of systems and assemblies and to create apparatus suitable for repeated use and in ensuring the high reliability of the entire complex. (Aviatsiya i Kosmonavtika, Moscow, No. 4, 1974, pp. 1–2.)

TASS reported that Soviet scientists have been searching for "OZMA"-type signals from extraterrestrial civilizations for the past 4 years. The search is being carried out by scientists from the Gorkiy Research Institute of Radio Physics led by Tsevolod Troitskiy, corresponding member of the U.S.S.R. Academy of Science. Troitskiy believes that there is a civilization in existence on one out of every thousand stars, and that in a sphere with a radius of 100 light years there may be several civilizations. (TASS, May 8, 1974, 1244 GMT.)

K. Kondratyev, Corresponding Member of the U.S.S.R. Academy of Sciences, said that space survey methods are exceptionally useful in dealing with the problems of protecting the environment and prospecting for natural resources. Space ecology has undergone evolution. The most serious contribution in this area will belong to the crews of manned spaceships and orbital stations. Visual observations by cosmonauts are of great value. Spectroscopy is becoming an increasingly important instrument of space ecology. Certain spectroscopic experiments cannot be carried out by automatic machines; they can be fulfilled successfully only by people. Broad possibilities are being opened up by the use of spectroscopy including discrimination of types of soil; characterization of the conditions of forests and crops; and detection of pollution in the oceans. He said that it is best to use apparatus (scanning multichannel radiometers) which gives images of the Earth's surface in a limited number of wavelengths. It is possible to select four of five wavelengths and obtain virtually all the information of interest. The use of complex radiospectroscopy equipment is even more promising than spectroscopy in the visible and infrared bands. The chief advantage of radio methods is their all-weather capability. Moreover, they enable remote sounding of the upper layer of the Earth's surface to be effected and, for example, the humidity of the soil to be determined at various depths. (Pravda, Moscow, July 21, 1974, p. 4.)

G. Beregovoy, Major General of Aviation, discussed the possibilities for manufacturing goods in space including the production of ideally pure metals, the fabrication of very fine lenses and the cultivation of crystals. The use of space for the manufacture of hollow, ideally

round bodies of different diameter, the manufacture of long-life bearings, and the significant improvement of bonding methods were also mentioned. He noted, however, that the practical accomplishment of these and other industrial processes in space requires that large space stations or factories be put into orbit. The station can have a mass of hundreds of tons. Nuclear power plants constructed on Earth, independently put into orbit, and subsequently docked to the orbiting factory may be the source of electricity, although solar technology may also be used. (Kryl'ya Rodiny, Moscow, No. 7, 1974, pp. 22–25.)

Academician B. Petrov said that large orbital stations assembled in orbit and lasting for several years (up to 10 years) with replacement crews of 12 to 20 people were possible, in principle, in the foreseeable future, but such projects will become expedient only when the possibilities of orbital stations with small crews have been exhausted and when the economic, scientific and technical advantages of such stations have been substantiated. In the distant future, one can speak of the expediency of elaborating plans for superlarge multipurpose orbital stations designed for a crew of 50 to 70 people increased later to up to 100 people or more. In addition, specialized unmanned stations visited regularly by cosmonauts will be established. He said "there is no doubt that ships used once only will be employed for a long time to come, and alongside this, transport ships used many times over will be created with high aerodynamic efficiency for controlling atmospheric descent with small load factors." (TASS, Moscow, August 6, 1974, 0830 GMT.)

General Shatalov reported that the Soviet Union is developing unmanned spacecraft "tankers" that would rendezvous with manned or unmanned Salyut space station vehicles to replenish their consumables and prolong their useful life in orbit. According to General Shatalov, the unmanned tanker vehicles would carry consumables such as reaction control system fuel with an added weight capacity due to absence of cosmonaut life support and reentry systems. A malfunction of a fully automatic rendezvous and docking system being tested for use by the Soyuz-like tanker vehicles prevented Soyuz 15 cosmonauts from docking with the Salyut 3 reconnaissance spacecraft on August 27, 1974. (Statement made during an Apollo-Soyuz Test Project training session at the Johnson Space Center [no specific date given.] Aviation Week & Space Technology, New York, September 16, 1974, p. 22.)

Cosmonaut Sevastyanov stated that future Soviet space technology will develop in two directions—toward more perfect automated systems and toward more perfect manned systems. Automated craft will in the next few decades explore increasingly remote regions of the solar system, land on and explore the Moon, Venus, and Mars. The use of manned systems for these tasks is uneconomical so far. He said that in the future huge manned orbital complexes assembled in space, will carry sophisticated technology and power plants, which will transmit through laser systems, energy directly from outer space. He praised cooperative international space activity and said that "in this rests the biggest and most promising prospects, the biggest contribution of cosmonautics to all mankind." (Prague CTK, October 9, 1974, 0800 GMT.)

Cosmonaut A. G. Nikolayev stressed the importance of satellites to the national economy. He also praised the Apollo-Soyuz Test Project. Of Soviet plans to explore the planets he said, "Further exploration of Venus, Mars and other planets of the solar system and of other systems will be carried out by automatic stations as well as by manned spaceships, but to construct such a spaceship is a very difficult affair requiring great expenses. In the future, it certainly will be a matter of many-sided cooperation." (Prague CTK, October 30, 1974, 0939 GMT.)

Academician Boris Petrov, Chairman of the Interkosmos Council stated in an *Izvestiya* interview that the development of orbiting space stations is an important stage in Soviet cosmonautics. An extensive research program can be carried out on space stations, manned by 2 to 3 people at a time. However, scientists and specialists from a number of countries are also working on the development of even larger stations. He mentioned three approaches to large stations: (1) Space stations can be injected into orbit in a fully assembled state, as is done today. (2) Stations can be designed in modules, each of which is sent into orbit by a separate carrier rocket. The modules are then docked together to form the space station. (3) Smaller units, assemblies, equipment and instrument modules are put into an "assembly" orbit by separate carrier rockets of different performance capability, and assembly is done with the help of cosmonauts and a special craft equipped for this purpose.

One may assume, he said, that large orbiting stations with a life of up to 10 years and crew exchanges of 12 to 20 people will be considered useful in the future. Extra-large multi-purpose stations with crews of 50 to 70 or even 100 people are predicted for the far distant future. Of further interest is the creation of specialized unmanned scientific orbiting stations which are periodically visited by cosmonauts for the purpose of checking and adjusting instruments. Later, large comfortable long-duration stations will have artificial gravity. Such projects, he said, are under discussion by specialists in various countries. Petrov also said it is necesary to have reusable transport craft with high aerodynamic qualities for re-entry. At this time existing orbital stations with crews of 2 to 3 are capable of carrying out the Soviet space research program successfully. The creation of larger stations, he said, is the business of future decades. (Spaceflight, London, November 1974, p. 402.)

Vladimir Shatalov, head of Soviet cosmonaut training, stated that the development of a reusable "space plane" is quite feasible. He says that the time is not far off when such a craft will make its first space flight. Shatalov emphasized the need for reusability of as many components of the system as possible. The most acceptable scheme for the Soviet program is an unmanned first stage and a piloted second stage with an aircraft configuration. *Flight Internationel* concluded from Shatalov's description that Russia may be well along in building an equivalent to the United States' space shuttle. (Flight International, London, December 5, 1974, p. 814.)

1975

Cosmonaut V. A. Shatalov expressed his conviction that the Apollo-Soyuz experiment can rightly be considered a qualitatively new stage

in the conquest of space, both technically and in the political sense. He said it was the Soviet hope that the linkup will be the first but not the last joint experiment. For the future, he said Soviet cosmonautics are concentrated on the development of long-duration orbital stations. One use of the stations will be to serve as a base for large diameter telescopes. He said scientists are seriously studying the possibility of establishing atomic power stations in space, as well as organizing the extraction of valuable raw materials on the planets and the manufacture of many articles which are impossible to produce under gravitational conditions. He said space manufacturing will produce such a saving even within a few years that all space expenditures will have been recouped. Also, it was his belief that "in the near future mankind will find a solution to the complex but nonetheless feasible technical problem of creating a space apparatus which can be used many times, a kind of 'space ferry' which will carry out shuttle trips from the Earth to the orbital stations and back." (Movoye Vremya, Moscow, January 3, 1975, pp. 20–24).

Physicist Rolan Kiladze reported that Mercury has a very rarefied atmosphere with a surface pressure about 10,000 times less than on Earth. The presence of an atmosphere on Mercury was established during observations of the planet as it crossed the solar disc. He said: "The discovery of 'air' on Mercury is of practical as well as scientific interest. For example, the design of space apparatuses to investigate the surface of the planet would now take into account of the possibility of a soft landing on Mercury." (TASS, Moscow, January 24, 1975, 1506 GMT.)

Dr. Yulian Novikov, a spokesman for the Space Research Institute, stated that the next stage in the orbital laboratories program will be the development of major orbital platforms capable of carrying a crew of tens of people. Global scientific and engineering tasks, he stressed, call for a global approach in pooling the efforts of various countries. He cited the Apollo-Soyuz Test Project as the first step to such a unification. He also reported that scientists are discussing the possibility of specialized unmanned stations to be regularly visited by scientists-cosmonauts for the adjustment and checkup of research equipment, replacement of magnetic and photographic tapes, and replacement and repairs of technical systems. Novikov's remarks were made during a news briefing on the status of the Salyut–4 flight. (TASS, Moscow, January 24, 1975, 1546 GMT.)

Unnamed authors of a book titled "Outer Space and the Weather" stated that the Soviet meteorological space service hopes to adopt shortly a "three-tier" system of weather observation. The first "tier" of such a system will be made up of long-duration orbiting stations at heights of several hundred kilometers. It will be their task to follow fast natural phenomena: cyclones, rising tides, dust storms and tsunami tidal waves. At a height of 1,000 to 1,500 kilometers there will be a number of Meteor satellites designed to gather data about planetary phenomena in the atmosphere. The upper tier, at a height of some 36,000 kilometers, will be made up of meteorological satellites for the observation of dynamic processes. (TASS, Moscow, February 4, 1975, 1437 GMT.)

Cosmonaut Yuriy Artyukhin was asked during an interview whether the Soviet space program envisages the use of satellites for the mili-

tary. His reply was "such a goal has not been set in our country." He told a news conference that weather and pollution watching, telecommunications, and mineral surveys are the applications envisaged in the Soviet space program. (Bombay PTI, February 5, 1975, 1530 GMT.)

Academician B. N. Petrov discussed the prospects for long-duration space stations and a reusable space transportation system. He said Salyut-class orbital stations are the most promising space system for the immediate future for use in solving an ever-increasing number of national tasks. However, in the distant future it may be expedient to build a station which will operate for years, about 10 years, perhaps, and will have a shift crew of 10 to 20 people. One can even look ahead to multipurpose supercomplexes designed for a crew of 50 to 70, even 100 people. To facilitate assembly of large stations it may be expedient to equip every modular component with its own engine and steering system necessary for docking. Another possibility for assembly would be to utilize a "space tug" which would maneuver components into position. The tug could be either manned or controlled from Earth. He also suggested it is essential to change the design of space delivery systems in such a way that they would be reusable. He said a space transportation system of the future should have a returnable first and, if need be, second stage. The orbital stage will resemble a modern high-speed aircraft. It will need small but very strong wings, possibly of variable geometry, that is, ones which fold up. Because the biological consequences of long-duration space flight are not fully understood, he said it cannot be ruled out that artificial gravity will need to be created on major orbital stations of the future. Rotation of the station is the only method for creating gravity and the station of the future will resemble either an enormous torus or a polyhedron made of vast cylinders, or two big cylinders linked by a long tunnel tube. It also seems advisable to have an individual non-rotating block within the station to simplify docking of transport ships and to carry out astronomical and Earth observation. (Trud, Moscow, February 5, 1975, p. 3.)

It was reported that individual Soviet scientists have sounded out National Aeronautics and Space Administration (NASA) officials on the possibility of flying some Soviet experiments in the United States space shuttle, and NASA is open to discussing the possibility. (Aviation Week & Space Technology, New York, March 3, 1975, p. 9.)

Academician R. Sagdeyev, in discussing Soviet space research planned through the next decade, stated that the principal objective of investigations of circumterrestrial space remains the study of the upper atmosphere, magnetosphere, and solar-terrestrial relationships. In a second research area, the Russians plan to obtain information concerning virtually all the planets of the solar system. A third research area he discussed related to the planetary investigations and the study of the origin of life, including life on other planets. He said that Mars is the most interesting planet in this respect. Also, decisions must be made in the near future concerning whether automated or manned spacecraft should be given preference in planetary investigations. Sagdeyev was certain that existing technical know-how is entirely adequate for organizing expeditions to either Venus or Mars. However, such flights would involve enormous costs and no country would now

spend so much on manned expeditions. He was confident that the principal volume of information about the planets could be obtained using automated spacecraft. He stressed that in the final analysis expensive space programs can be carried out only by combining the efforts of different countries. He cited the Apollo-Soyuz Test Project as an important step in carrying out such major international projects. (Trud, Moscow, April 12, 1975, p. 2.)

Academician G. I. Petrov said that goals in radio astronomy will require the development of large space-based antenna systems. Cosmonauts may take an active part in their installation, adjustment, operation, repair and modernization. He said very large orbital stations are not justified at this time. Small stations with the possibility of adding to the structure are considerably more effective. The establishment of permanent, inhabited bases on other planets is also somewhat premature. Even given all the necessary conditions, the performance of prolonged research on the surface of, say, Mars with human participation will hardly be justified in the next few years. He said there can be no doubt that long-term research on the surface of other planets should be carried out by automated laboratory-stations. Stations representing a combination of a Lunokhod equipped with manipulators controlled from Earth and a recoverable apparatus of the Luna 16 type are very promising for this purpose. Concerning lunar exploration, he said orbital stations transported to the Moon with the help of tugs would be useful. Men could land at interesting sites for a short while for exploring, but a permanent station on the lunar surface would give little in this respect, since means of transport on its surface will remain limited for a long time. He said that the technique of sounding from orbital stations across a wide band of the radiation spectrum is opening up new possibilities for studying the Earth. He discussed "tempting ideas and proposals" opening up for cosmonautics such as: the importance of procuring rock samples from the planet Mars in order to determine if life exists there; the opportunities for the production of high-purity substances and precision instruments in the space environment; the possibility of approaching a comet for close study; and the necessity of flight around the Sun out of the plane of the ecliptic to study solar winds. (Pravda, Moscow, April 12, 1975, p. 3.)

G. Beregovoy, Pilot Cosmonaut U.S.S.R., said that communication by artificial Earth satellites will develop further as an integral part of the country's communications network. This development will complement television broadcasting, and by 1980 he predicted it will cover the entire area of the Soviet Union. For planetary exploration, he said that still more perfect automatic vehicles will be developed which will be capable of solving a wide range of scientific problems. Special note was made of Martian rovers. He said that orbital scientific stations and transport ships for servicing them afford broad possibilities for the study of space and the practical use of the results. Soviet science regards such stations to be man's principal route into space. Besides being used as scientific laboratories for observing Earth, orbital stations can be used as launch pads for flights to other planets. The Soviet space program provides for a harmonic combination of manned and automatic vehicles. He said that automatic space vehicles can do much and assist in much, but only man can effectively conquer space. "A real conquest of space is impossible without the direct participation

of man with his emotional perception of his surroundings, with his capacity for making decisions in situations which unexpectedly arise." (Aviatsiya i Kosmonavtika, Moscow, No. 4, 1975, pp. 1–3.)

I. Svetlov, Director of the Scientific Research Center for Study of the Environment and Natural Resources, Hydrometeorological Service U.S.S.R., discussed the role of artificial Earth satellites in meteorology. He said that the possibilities for the use of satellites in meteorology will be expanded. He said a plan is now being discussed for creating a single international network for observing the world oceans by the use of automatic buoys, the information from which will be collected by satellites. He said the Russians are also considering an international global system of geostationary meteorological satellites which will be positioned over the Equator at an altitude of 36,000 km. A system of five such satellites scanning a zone along the Equator from 50 degrees north to 50 degrees south latitude is envisioned. He said that a combination of geostationary and low-orbit satellites will make possible a considerable improvement in meteorological information. (Izvestiya, Moscow, May 1, 1975, p. 5.)

Professor K. P. Feoktistov said that while it is possible to create orbital manned stations which are capable of operating successfully over many months and even a year or more, the biological consequences to the human organism resulting from long periods of weightlessness are for the time being far from clear. Despite the United States' experience with long-duration manned spaceflight, he said that Soviet scientists feel that it is not desirable to strive for records for presence in space, but for the time being are making more detailed studies of the behavior of the human body during the first weeks of life in orbit. (Krasnaya Zvezda, Moscow, May 28, 1975, p. 3.)

G. Moskalenko discussed various vehicles which might be used to investigate the Venerian atmosphere. He said that studies carried out at the Space Research Institute of the U.S.S.R. Academy of Sciences show that the most promising vehicles capable of exploring the atmosphere of a planet for a long time are the subsonic or glider-type aircraft, or one of the Lunokhod types which could analyze samples of ground over different sectors of the surface. Scientists, he said, assume that aerostatic-type vehicles are extremely promising for investigating the Venerian atmosphere: these are filled with a light gas, such as helium, have a soft envelope and can drift at a definite altitude above the planetary surface. Because of similarities in atmospheres, he said that it is possible to use flightcraft with the aerodynamic characteristics of terrestrial analogues. Vehicles which are a combination of dirigible and aircraft are of definite interest. In the dense Venerian atmosphere such a combination is particularly advantageous because it ensures a high maneuverability and a considerable lightening of the transport ship. (Komsomol'skaya Pravda, Moscow, June 14, 1975, p. 4.)

K. Bushuyev, Technical Director of the Apollo-Soyuz Test Project for the U.S.S.R., commented on the implications of the ASTP flight for future cooperative space efforts between the U.S.S.R. and the United States and between other nations. He said that the project creates broad possibilities for the further mastery of space and will make it possible to carry out complex experiments in the future on an international basis. The project yields valuable experience in orga-

nizing interactions between nations in the conduct of major scientific research projects. He said, however, that the development of such cooperation is conceivable only under conditions of peaceful coexistence. He added that "the Communist Party and the Soviet Government are following a firm policy of strengthening peace over the entire Earth and Soviet scientists see it as their duty to support this course by the broadening of scientific contacts with scientists of different countries." (Pravda, Moscow, June 29, 1975, p. 3.)

Academician R. Z. Sagdeyev, Director of the Space Research Institute U.S.S.R. Academy of Sciences, discussed the possibilities for future international cooperation in space research and the implications of the Apollo-Soyuz Test Project flight for future Soviet-American cooperation. He said that the ASTP flight is an important stage in the development of cooperation between the U.S.S.R. and the United States in the investigation of space for the welfare of man. He said that it must be assumed that the project will serve as a basis for other joint projects in this field. In Sagdeyev's opinion, the preparations for this project represent the optimum forms of international cooperation and that such forms will undoubtedly be used in the future. Prospects for joint international space programs of the future include manned flight to the planets, improvement of global radio and television systems, and a number of other projects which require a generalization of experience in the scientific and technical advances of different countries. He said that the years 1977–1978 have been announced as international years for investigating the magnetosphere. It is proposed that about 50 spacecraft of many countries will carry out coordinated experiments. Soviet and French scientists, he said, are jointly discussing the problems involved in investigating Venus and its atmosphere by means of inflatable balloons and simultaneously with artificial Earth satellites. Sagdeyev also said that "orbital beacons" satellites which would support air and oceanic navigation, and satellites for investigating the Earth's natural resources and oceans, should both have an international character. (Pravda, Moscow, July 24, 1975, p. 2.)

Academician V. Glushko, in a discussion of orbital space stations, said that physiological problems associated with weightlessness are the principal stumbling block in the present stage of the Soviet manned space program. While it is possible to rotate a station to create artificial gravity, he said that observations requiring a definite and constant orientation would be difficult to make. He said that the designers of the Salyut stations are gradually approaching the ideal in which operations auxiliary to scientific research are carried out by automated systems. As an example, Glushko cited the "Kaskad" system for the automatic orientation of Salyut-4. "Kaskad" made it possible to reduce fuel consumption "by several times." Salyut-4 also utilized an autonomous navigation system which included a complex of sensors and an on-board computer, supported by Earth-based information centers. In the future, he said that the entire navigational support of the flight will be the crew's responsibility. On another topic, he said that closed cyclings of matter are gradually being introduced in life support systems. Systems tested by the Salyut cosmonauts are prototypes of future space greenhouses which not only close the cycling of air and water, but also will supply the cosmonauts with fresh vege-

tables, berries, fruit and wheat. Without such systems he said that long-term space stations are unthinkable. Glushko said, too, that the benefits derived from the space program thus far "are only the outlines of the grandiose future. Cosmonautics, without question, is becoming one of the most important branches of the national economy." (Izvestiya, Moscow, July 27, 1975, pp. 1, 3.)

Konstantin Bushuyev, Technical Director of the Apollo-Soyuz mission, said, "the experience of cooperation and the newly found forms of organization (resulting from the mission) pin a good foundation under the continued development of constructive contacts between the Soviet and American experts in the exploration and use of outer space for peaceful purposes and the benefit of world science." (TASS, Moscow, Aug. 5, 1975, 0555 GMT.)

Yu. Matusevich discussed the development of automatic control systems (ACS) for spacecraft. Whereas in the last decade the control of spacecraft was based on analog techniques in the form of multiregime automatic systems with switchings performed by command from Earth, Matusevich said that at the present time there has been a changeover to control systems of a higher class using on-board digital computers. Computers afford the possibility for the adoption of the optimum laws of terminal control, i.e., control whose purpose it is to deliver an object to the end point of a flight, at the same time that its momentary positions on the entire trajectory can be quite arbitrary. In the future, he said that the use of terminal ACS will make it possible to create self-optimizing flexible control programs with recognition of the actual current situation, which changes randomly. (Aviatsiya i Kosmonavtika, Moscow, No. 8, pp. 42–43.)

Academician Boris Petrov stressed the great importance the Soviet space program attaches to automatic vehicles in the exploration of outer space. He said, "For many years ahead the planets of the Solar System will be explored by 'automatic cosmonauts'. The flights of unmanned space stations still come first in the foreseeable future." He said that the Luna 16 mission which returned from the Moon with soil samples opened new ways for improving control systems in general and that the mission marked the beginning of "a new important trend in the development of space exploration by automatic probes." (TASS, Moscow, Sept. 21, 1975, 1552 GMT.)

Vladlen Vereshchetin, Vice Chairman of the Interkosmos Council, the Academy of Sciences of the U.S.S.R., said that the European Conference on Security and Cooperation opened up new opportunities for an extensive development of international cooperation in the exploration and use of outer space. He stressed that the present stage in the Soviet Union's international cooperation in space research is characterized by the drafting of bilateral and multilateral cooperation programs for long periods. He said: "The cooperating states now pass from individual experiments to the realization of long-term programs." He said that his country "wants such projects to promote the development of all around ties between states and to fill the process of relaxation of tension with concrete content." (TASS, Moscow, Nov. 1, 1975, 1219 GMT.)

APPENDIX A

TABLE OF SOVIET SPACE LAUNCHES, 1957–1975

Compiled by Charles S. Sheldon II (in collaboration with Barbara M. DeVoe for the earlier years) and with computer input by Carol B. Garrett and Christine Anderson

This record has been compiled on the basis of TASS bulletins of launch and orbital information. Where orbital information and decay or weight information was not supplied by the Soviet Government, first resort was made to the data of the Royal Aircraft Establishment, Farnborough, and further supplemented in a few cases from the National Aeronautics and Space Administration Goddard Satellite Situation Reports. Identification of launch site, launch vehicle, and mission has been developed in a synergistic fashion between this appendix and the analytical tables in the main text of this report, through observation of repetitive patterns in the data.

In a few cases, such substantial changes in the locations of orbits occurred that it has been useful to list more than one orbit. Those payloads in heliocentric orbit have their elements listed in astronomical units (AU) and their inclinations to the plane of the ecliptic, while their periods are listed in days (D) rather than minutes.

Where decay dates are given, the total duration of flight is also shown in days contained as a figure in parentheses.

It should be remembered that such a tabulation is subject to further revision particularly as objects decay from orbit (including controlled landings on Earth or on other celestial bodies).

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
	1957	1957											
Sputnik 1	Alpha 1	Oct 4	1912	TT	A	84	947	227	65.1	96.2	Jan 4(92)	Dec 1(58)	World'a first satellite.
Sputnik 2	Beta 1	Nov 3	0224	TT	A	508	1,671	225	65.3	103.7	Apr 14(162)	Attached	Biological flight. No recovery.
	1958	1958											
Sputnik 3	Delta 2	May 15	0712	TT	A	1,327	1,881	226	65.2	106.0	Apr 6(692)	Dec 3(202)	Orbiting geophysical observatory.
	1959	1959											
Luna 1	Mu 1	Jan 2	1702	TT	A-1	361	1.32 au	0.98 au	0.01	450 D	solar orbit	solar orbit	Missed Moon by 5-6,000 Km, Jan 4, 1959.
Luna 2	Xi 1	Sep 12	1102	TT	A-1	390	----	----	----	---	Sep 13(1)	Sep 13(1)	Struck Moon 435 Km from visible center(1 W,30 N)
Luna 3	Theta 1	Oct 4	0224	TT	A-1	435	476,500	40,300	73.8	22,700.0	Apr 20(198)	Mar 20(167)	Passed Moon at 6,200 Km Oct 10, 1959. Photos far side.
	1960	1960											
Korabl Sputnik 1	Epsilon 1	May 15	0000	TT	A-1	4,540	369	312	65.0	91.2	Oct 15(1979)	Jul 17(63)	Precursor to manned; recovery failed when incorrect attitude at retrofire on 64th orbit.
Korabl Sputnik 2	Lambda 1	Aug 19	0838	TT	A-1	4,600	339	306	65.0	90.7	Aug 20(1)	Sep 23(35)	Precursor to manned; recovered.
Unannounced Mars	None None	Oct 10	----	TT	A-2-e	640?	---	---	---	---	Oct 10(0)	Oct 10(0)	Mars attempt failed to reach Earth orbit.n
Unannounced Mars	None None	Oct 14	----	TT	A-2-e	640?	---	---	---	---	Oct 14(0)	Oct 14(0)	Mars attempt failed to reach Earth orbit.
Korabl Sputnik 3	Rho 1	Dec 1	0726	TT	A-1	4,563	265	187	65.0	88.6	Dec 2(1)	Dec 2(1)	Precursor to manned; recovery failed, burned.
	1961	1961											
Tyazheliy Sputnik 4	Beta 1	Feb 4	0224	TT	A-2-e	6,483	328	224	65.0	89.8	Feb 26(22)	Feb 13(9)	Venus attempt. Orbiting platform failed to launch
Venera	Beta 1					640?							
Tyazheliy Sputnik 5	Gamma 3	Feb 12	0210	TT	A-2-e	6,475	319	198	65.0	89.7	Feb 25(13)	Feb 18(6)	Launched Venera 1
Venera 1	Gamma 1					644	1.02 au	0.72 au	0.58	300 D	solar orbit	solar orbit	Passed Venus at 100,000 Km in May. Contact lost Feb 27.

Korabl Sputnik 4	Theta 1	Mar 9	0629	TT	A-1	4,700	249	184	64.9	88.5	Mar 9(0)	Mar 10(1)	Precursor to Manned. Recovered.
Korabl Sputnik 5	Iota 1	Mar 25	0600	TT	A-1	4,695	247	178	64.9	88.4	Mar 25(0)	Mar 26(1)	Precursor to manned. Recovered.
Vostok 1	Mu 1	Apr 12	0600	TT	A-1	4,725	327	181	65.0	89.1	Apr 12(0)	Apr 16(4)	Gagarin. Recovered.
Vostok 2	Tau 1	Aug 6	0600	TT	A-1	4,731	257	178	64.9	88.6	Aug 7(1)	Aug 9(3)	Titov. Recovered.
Kosmos 1	<u>1962</u> Theta 1	<u>1962</u> Mar 16	1200	KY	B-1		980	217	49.0	96.4	May 25(70)	Jun 18(94)	First Kapustin Yar launch Particle measurements.
Kosmos 2	Iota 1	Apr 6	1717	KY	B-1		1,546	212	49.0	102.3	Aug 20(501)	Oct 6(183)	Particle and radiation measurements.
Kosmos 3	Nu 1	Apr 24	0405	KY	B-1		720	229	49.0	93.8	Oct 17(176)	Aug 5(103)	Particle and radiation measurements.
Kosmos 4	Xi 1	Apr 26	1005	TT	A-1		330	298	65.0	90.6	Apr 29(3)	Jun 17(52)	Observation. Recovered.
Kosmos 5	Upsilon 1	May 28	0307	KY	B-1		1,600	203	49.1	102.8	May 2(330)	Dec 15(201)	Particle and radiation measurements.
Kosmos 6	Alpha Delta 1	Jun 30	1605	KY	B-1		360	274	49.0	90.6	Aug 8(39)	Sep 8(70)	Cosmic radiation measurements.
Kosmos 7	Alpha Iota 1	Jul 28	0922	TT	A-1		369	210	65.0	90.1	Aug 1(4)	Aug 21(24)	Observation. Probably recovered.
Vostok 3	Alpha Mu 1	Aug 11	0824	TT	A-1	4,722	251	183	65.0	88.5	Aug 15(4)	Aug 14(3)	Nikolayev. Recovered.
Vostok 4	Alpha Nu 1	Aug 12	0755	TT	A-1	4,728	254	180	65.0	88.5	Aug 15(3)	Aug 14(2)	Popovich near co-orbit 6.5 Km. Recovered.
Kosmos 8	Alpha Xi 1	Aug 18	0502	KY	B-1		604	256	49.0	92.9	Aug 17(365)	Dec 19(123)	Micrometeorites, atmospheric density
Unannounced	Alpha Pi 1	Aug 25	0253	TT	A-2-e		252	173	64.9	88.7	Aug 28(3)	Sep 2(8)	Venus attempt failed to leave Earth orbit.
Venera	Alpha Pi 1					890?							
Unannounced	Alpha Tau 1	Sep 1	----	TT	A-2-e		310	180	64.9	89.4	Sep 6(5)	Sep 3(2)	Venus attempt failed to leave Earth orbit.
Venera	Alpha Tau 3	890?									Oct 1(30)	attached	
Unannounced	Alpha Phi 1	Sep 12	0141	TT	A-2-e		213	186	64.9	88.5	Sep 14(2)	Sep 12(0)	Venus attempt failed to Leave Earth orbit.
Venera	Alpha Phi 3					890?	213	186	64.9	88.5	Sep 17(5)	attached	

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Kosmos 9	Alpha Omega 1	Sep 27	0936	TT	A-1		358	301	65.0	90.9	Oct 1(4)	Dec 22(86)	Observation. Probably recovered.
Kosmos 10	Beta Zeta 1	Oct 17	0922	TT	A-1		380	210	65.0	90.2	Oct 21(4)	Nov 5(19)	Observation. Probably recovered.
Kosmos 11	Beta Theta 1	Oct 20	0350	KY	B-1		921	245	49.0	96.1	May 18(576)	Jun 5(229)	Ion and atmospheric density
Unannounced Mars	Beta Iota 1 Beta Iota 1	Oct 24	1755	TT	A-2-e	890?	485	180	64.9	91.2	Oct 29(5)	Dec 22(59) attached	Mars attempt failed to leave Earth orbit.
Tyazheliy Sputnik	Beta Nu 1	Nov 1	1615	TT	A-2-e		243	174	64.9	88.5	Nov 3(2)	Nov 3(2)	Launched Mars 1
Mars 1	Beta Nu 3					894	1.60 au	0.92 au	2.68	519 D	solar orbit	solar orbit	Passed Mars at 193,000 Km. Communications failed Mar 21 at 106 million Km.
Unannounced Mars	Beta Xi 1 Beta Xi 3	Nov 4	1536	TT	A-2-e	890?	271 590	191 197	64.8 64.7	88.9 92.4	Nov 5(1) Jan 19(76)	Nov 8(4) attached	Mars attempt failed to leave Earth orbit
Kosmos 12	Beta Omega 1	Dec 22	0922	TT	A-1		405	211	65.0	90.5	Dec 30(8)	Jan 22(31)	Observation. Probably recovered.
	1963	1963											
Unannounced Luna	1A 1A	Jan 4	0712	TT	A-2-e	1,400?	196	167	65.0	88.5	Jan 5(1)	Jan 11(7) attached	Moon attempt failed to leave Earth Orbit.
Kosmos 13	6A	Mar 21	0824	TT	A-1		337	205	65.0	89.8	Mar 29(8)	Apr 9(19)	Observation. Probably recovered.
Tyazheliy Sputnik	8A	Apr 2	0817	TT	A-2-e		297	167	64.7	88.2	Apr 3(1)	Apr 3(1)	Launched Luna 4.
Luna 4	8B					1,422	700,000	90,000	65.0	42,000.0	Baryc. orbit	Baryc. orbit	Passed Moon at 8,500 km on Apr 6.
Kosmos 14	10A	Apr 13	1102	KY	B-1		512	265	49.0	92.1	Aug 29(138)	Jul 6(84)	Test of meteorological equipment
Kosmos 15	11A	Apr 22	0824	TT	A-1		371	173	65.0	89.8	Apr 27(5)	May 1(9)	Observation. Probably recovered.
Kosmos 16	12A	Apr 28	0936	TT	A-1		401	207	65.0	90.4	May 8(10)	May 20(22)	Observation. Probably recovered.
Kosmos 17	17A	May 22	0307	KY	B-1		788	260	49.0	94.8	Jun 2(742)	Apr 2(316)	Particle and radiation measurements

Kosmos 18	18A	May 24	1048	TT	A-1		301	209	65.0	89.4	Jun 2(9)	Jun 8(15)	Observation. Probably recovered.
Vostok 5	20A	Jun 14	1200	TT	A-1	4,720	222	175	65.0	88.3	Jun 19(5)	Jun 15(2)	Bykovskiy. Recovered.
Vostok 6	23A	Jun 16	0936	TT	A-1	4,713	233	183	65.0	88.3	Jun 19(3)	Jun 18(2)	Tereshkova. Crossing pass at 5 Km. Recovered.
Kosmos 19	33A	Aug 6	0600	KY	B-1		519	270	49.0	92.2	Mar 30(237)	Dec 9(125)	Cosmic radiation and atmospheric density.
Kosmos 20	40B	Oct 18	0936	TT	A-1		311	206	65.0	89.6	Oct 26(8)	Oct 29(12)	Observation. Probably recovered.
Polet 1	43A	Nov 1	0853	TT	A-m		1,437	343	58.9	102.5	Nov 23(1087)	attached	Maneuverable.
Tyazheliy Sputnik	44A	Nov 11	0629	TT	A-2-e	960?	229	195	64.8	88.5	Nov 14(3)	Nov 12(1)	Possible planetary precursor failure.
Kosmos 21	44A												
Kosmos 22	45A	Nov 16	1048	TT	A-2		394	205	64.9	90.3	Nov 22(6)	Dec 3(17)	Observation. Probably recovered.
Kosmos 23	50A	Dec 13	1355	KY	B-1		613	240	49.0	92.9	Mar 27(105)	Mar 6(84)	Test of meteorological equipment.
Kosmos 24	52A	Dec 19	0922	TT	A-1		408	211	65.0	90.5	Dec 28(9)	Jan 25(37)	Observation. Probably recovered.
	1964	1964											
Elektron 1 Elektron 2	6A 6B	Jan 30	0936	TT	A-1	330 445	7,100 68,200	406 460	61.0 61.0	169.0 1,360.0			Dual launch orbiting geophysical observatories. Possible also nuclear detection.
Kosmos 25	10A	Feb 27	1326	KY	B-1		526	272	49.0	92.3	Nov 21(268)	Jun 18(112)	Cosmic radiation.
Kosmos 26	13A	Mar 18	1507	KY	B-1		402	271	49.0	91.0	Sep 28(194)	May 17(60)	Magnetic fields.
Kosmos 27 Venera	14A 14B	Mar 27	0322	TT	A-2-e	 960?	237 194	192 181	64.8 64.8	88.7 88.2	Mar 28(1) Mar 29(2)	Mar 29(2)	Venus attempt failed to leave Earth orbit.
Tyazheliy Sputnik	16A	Apr 2	0253	TT	A-2-e		213	187	64.8	88.5	Apr 3(1)	Apr 2(0)	Launched Zond 1.
Zond 1	16D					960?	1.06 au	0.65 au	3.7	274 D	solar orbit	solar orbit	Passed Venus at 100,000 Km. July 19. Communications failed after May 14.
Kosmos 28	17A	Apr 4	0936	TT	A-1		395	209	65.0	90.4	Apr 12(8)	May 3(29)	Observation. Probably recovered.
Polet 2	19B	Apr 12	0922	TT	A-m		500	310	58.1	92.4	Jun 8(787)	May 1(19)	Maneuverable.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Kosmoa 29	21A	Apr 25	1019	TT	A-1		309	204	65.1	89.5	May 3(8)	May 11(16)	Observation. Recovered.
Kosmoa 30	23A	May 18	0950	TT	A-2		383	207	64.9	90.2	May 26(8)	Jun 7(20)	Observation. Probably recovered.
Kosmoa 31	28A	Jun 6	0600	KY	B-1		508	228	49.0	91.6	Oct 20(136)	Aug 16(71)	Military.
Koamos 32	29A	Jun 10	1048	TT	A-1		333	209	51.3	89.8	Jun 18(8)	Jul 14(34)	Observation. Recovered.
Koamoa 33	33A	Jun 23	1019	TT	A-1		293	209	65.0	89.4	Jul 1(8)	Jul 10(17)	Observation. Probably recovered.
Kosmos 34	34A	Jul 1	1117	TT	A-2		360	205	65.0	90.0	Jul 9(8)	Jul 15(14)	Observation. Probably recovered.
Elektron 3 Elektron 4	38A 38B	Jul 10	2150	TT	A-1	350 444	7,040 66,235	405 459	60.9 60.9	168.0 1314.0			Dual launch. Orbiting geophysical observatories. Possible also nuclear detection.
Kosmos 35	39A	Jul 15	1131	TT	A-1		268	217	51.3	89.2	Jul 23(8)	Aug 1(17)	Observation. Probably recovered.
Kosmoa 36	42A	Jul 30	0336	KY	B-1		503	259	49.0	91.9	Feb 28(213)	Nov 29(122)	Military.
Kosmoa 37	44A	Aug 14	0936	TT	A-1		300	205	65.0	89.5	Aug 22(8)	Sep 3(20)	Observation. Probably recovered.
Koamos 38 Koamos 39 Kosmos 40	46A 46B 46C	Aug 18	0922	TT	C-1		876 876 876	210 210 210	56.2 56.2 56.2	95.2 95.2 95.2	Nov 8(82) Nov 17(91) Nov 18(92)	Feb 19(185)	Triple launch. Development.
Tyazheliy Sputnik	49A	Aug 22	0712	TT	A-2-e		455	200	64.7	91.1	Sep 15(24)	Sep 28(37)	Launched Kosmos 41.
Kosmos 41	49D						39,855	394	64.0	715.0			Precursor to Molniya 1.
Kosmos 42 Kosmoa 43	50A 50C	Aug 22	1102	KY	B-1		1,099 1,099	232 232	49.0 49.0	97.8 97.8	Dec 19(484) Dec 27(492)	Aug 2(345)	Dual launch. Possible tests of communications satellite.
Kosmoa 44	53A	Aug 28	1619	TT	A-1		860	618	65.0	99.5			Precursor to weather satellite.
Kosmoa 45	55A	Sep 13	0950	TT	A-2		327	206	64.9	89.7	Sep 18(5)	Sep 27(14)	Observation and meteorological test. Recovered.
Kosmos 46	59A	Sep 24	1200	TT	A-1		271	215	51.3	89.2	Oct 2(8)	Oct 7(13)	Observation. Probably recovered.

Koamos 47	62A	Oct 6	0712	TT	A-2	5,000?	413	177	64.8	90.0	Oct 7(1)	Oct 14(8)	Precursor to manned. Probably recovered.
Voskhod 1	65A	Oct 12	0726	TT	A-2	5,320	409	178	65.1	90.1	Oct 13(1)	Oct 20(8)	Komarov, Yegorov, Feoktistov. Recovered.
Kosmos 48	66A	Oct 14	0950	TT	A-1		295	203	65.1	89.4	Oct 20(6)	Oct 28(14)	Observation. Probably recovered.
Kosmos 49	69A	Oct 24	0517	KY	B-1		490	260	49.0	91.8	Aug 21(301)	Feb 10(109)	Magnetic fields, IR & UV radiation.
Kosmoa 50	70A	Oct 28	1048	TT	A-1		241	196	51.3	88.7	Nov 5(8)	Nov 2(5)	Observation. Exploded before recovery.
Tyazheliy Sputnik	78A	Nov 30	1312	TT	A-2-e		219	153	64.7	88.2	Dec 1(1)	Dec 2(2)	Launched Zond 2.
Zond 2	78C					960?	1.52 au	0.98 au	6.40	508 D	solar orbit	solar orbit	Passed Mars at 1,500 km Aug 6. Communicationa failed.
Kosmoa 51	80A	Dec 9	2302	KY	B-1		554	264	48.8	92.5	Nov 14(340)	May 11(153)	Luminosity of stellar background.
Koamoa 52	1965 1A	1965 Jan 11	0936	TT	A-1		304	205	65.0	89.5	Jan 19(8)	Jan 29(18)	Observation. Probably recovered.
Kosmoa 53	6A	Jan 30	0936	KY	B-1		1,192	227	48.8	98.7	Aug 12(559)	Jan 11(346)	Cosmic ray and other radiation.
Kosmoa 54	11A	Feb 21	1102	TT	C-1		1,856	280	56.1	106.2	Sep 15(1302)	Dec 23(1766)	Triple launch. Development.
Kosmoa 55	11B						1,856	280	56.1	106.2	Feb 2(1076)		
Kosmoa 56	11C						1,856	280	56.1	106.2	Nov 2(984)		
Kosmos 57	12A	Feb 22	0741	TT	A-2	5,500?	512	175	64.8	91.1	Feb 22(0)	Mar 6(12)	Precursor to manned Probably exploded.
Koamos 58	14A	Feb 26	0502	TT	A-1		659	581	65.0	96.8			Precursor to weather satellite.
Kosmos 59	15A	Mar 7	0907	TT	A-2		339	209	65.0	89.7	Mar 15(8)	Mar 19(12)	Observation. Probably recovered.
Kosmos 60	18A	Mar 12	0936	TT	A-2-e		287	201	64.7	89.1	Mar 17(5)	Mar 17(5)	Moon attempt failed to leave Earth orbit.
Luna	18A					1,470							
Kosmos 61	20A	Mar 15	1102	TT	C-1		1,837	273	56.0	106.0	Jan 15(1036)	Aug 5(508)	Triple launch. Carrier rocket later exploded. Development.
Kosmos 62	20B						1,837	273	56.0	106.0	Sep 24(1280)		
Kosmos 63	20C						1,837	273	56.0	106.0	Nov 4(965)		
Voskhod 2	22A	Mar 18	0658	TT	A-2	5,682	495	173	65.0	90.9	Mar 19(1)	Mar 27(9)	Belyayev, Leonov. Recovered.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Kosmos 64	25A	Mar 25	1005	TT	A-1		271	206	65.0	89.2	Apr 2(8)	Apr 4(10)	Observation. Recovered.
Kosmos 65	29A	Apr 17	0950	TT	A-2		342	210	65.0	89.8	Apr 25(8)	May 6(19)	Observation and meteorological test. Recovered.
Tyazheliy Sputnik	30B	Apr 23	0211	TT	A-2-e		801	196	64.8	94.5	Jul 20(88)	Jul 2(70)	Launched Molniya 1-1.
Molniya 1-1	30A						39,957	548	65.0	720.0			Communications satellite.
Kosmos 66	35A	May 7	0930	TT	A-1		291	197	65.0	89.3	May 15(8)	May 24(17)	Observation. Probably recovered.
Tyazheliy Suptnik	36B	May 9	0755	TT	A-2-e		217	151	64.8	88.3	May 10(1)	May 10(1)	Launched Luna 5.
Luna 5	36A					1,476	---	---	---	---	May 12(3)	baryc orbit	Struck Moon at 31 S 8 W May 12.
Kosmos 67	40A	May 25	1048	TT	A-2		350	207	51.8	89.0	Jun 2(8)	Jun 4(10)	Observation. Recovered.
Tyazheliy Sputnik	44B	Jun 8	0741	TT	A-2-e		246	167	64.8	88.7	Jun 12(4)	Jun 10(2)	Launched Luna 6.
Luna 6	44A					1,442	---	---	---	---	solar orbit	baryc orbit	Passed Moon at 160,000 Km on Jun 11.
Kosmos 68	46A	Jun 15	1005	TT	A-1		334	205	65.0	89.8	Jun 23(8)	Jul 7(22)	Observation. Probably recovered.
Kosmos 69	49A	Jun 25	0950	TT	A-2		332	211	65.0	89.7	Jul 3(8)	Jul 6(11)	Observation. Probably recovered.
Kosmos 70	52A	Jul 2	0639	KY	B-1		1,154	225	48.8	98.3	Dec 18(534)	Jun 6(339)	Military.
Kosmos 71	53A	Jul 16	0336	TT	C-1		550	550	56.1	99.5	Aug 11(1852)		Quintuple launch.
Kosmos 72	53B						550	550	56.1	99.5			
Kosmos 73	53C						550	550	56.1	99.5	Mar 20(3069)		Development.
Kosmos 74	53D						550	550	56.1	99.5			
Kosmos 75	53E						550	550	56.1	99.5			
Proton 1	54A	Jul 16	1117	TT	D	12,200	627	190	63.5	92.5	Oct 11(87)	Sep 18(64)	Cosmic ray measurements.
Tyazheliy Suptnik	56B	Jul 18	1438	TT	A-2-e		210	164	64.8	88.7	Jul 20(2)	Jul 21(3)	Launched Zond 3.
Zond 3	56A					960	1.5 au	0.9 au	---	500 D	solar orbit	solar orbit	Passed Moon at 9,200 Km July 20.

Kosmos 76	59A	Jul 23	0434	KY	B-1		531	261	48.8	92.2	Mar 16(236)	Dec 4(134)	Military.
Kosmos 77	61A	Aug 3	1102	TT	A-2		291	200	51.8	89.3	Aug 11(8)	Aug 8(5)	Observation. Probably recovered.
Kosmos 78	66A	Aug 14	1117	TT	A-1		329	206	69.0	89.8	Aug 22(8)	Sep 3(20)	Observation. Probably recovered.
Kosmos 79	69A	Aug 25	1019	TT	A-2		359	211	64.9	90.0	Sep 2(8)	Sep 7(13)	Observation. Probably recovered.
Kosmos 80	70A	Sep 3	1355	TT	C-1		1,500	1,500	56.0	116.6			Quintuple launch. Possible communications satellites.
Kosmos 81	70B						1,500	1,500	56.0	116.6			
Kosmos 82	70C						1,500	1,500	56.0	116.6			
Kosmos 83	70D						1,500	1,500	56.0	116.6			
Kosmos 84	70E						1,500	1,500	56.0	116.6			
Kosmos 85	71A	Sep 9	0936	TT	A-2		319	212	65.0	89.6	Sep 17(8)	Sep 18(9)	Observation. Probably recovered.
Kosmos 86	73A	Sep 18	0755	TT	C-1		1,690	1,380	56.0	116.7			Quintuple launch. Possible communications satellites.
Kosmos 87	73B						1,690	1,380	56.0	116.7			
Kosmos 88	73C						1,690	1,380	56.0	116.7			
Kosmos 89	73D						1,690	1,380	56.0	116.7			
Kosmos 90	73E						1,690	1,380	56.0	116.7			
Kosmos 91	74A	Sep 23	0907	TT	A-2		342	212	65.0	89.8	Oct 1(8)	Oct 4(11)	Observation. Recovered.
Tyazheliy Sputnik	77C	Oct 4	0755	TT	A-2-e		286	129	64.8	88.6	Oct 5(1)	Oct 4(0)	Launched Luna 7.
Luna 7	77A					1,506	---	---	---	---	Oct 7(3)	barvc orbit	Struck Moon at 9 N 40 W Oct 7.
Tyazheliy Sputnik	80D	Oct 13	1941	TT	A-2-e		424	198	64.8	91.2	Nov 16(34)	Nov 8(25)	Launched Molniya 1-2.
Molniya 1-2	80A						40,000	500	65.0	719.0	Mar 17(516)	Jan 18(455)	Communications satellite.
Kosmos 92	83A	Oct 16	0824	TT	A-2		353	212	65.0	89.9	Oct 24(8)	Oct 29(13)	Observation and meteorological test. Recovered.
Kosmos 93	84A	Oct 19	0546	KY	B-1		522	220	48.4	91.7	Jan 3(77)	Nov 17(29)	Military.
Kosmos 94	85A	Oct 28	0824	TT	A-2		293	211	65.0	89.3	Nov 5(8)	Nov 3(6)	Observation. Probably recovered.
Proton 2	87A	Nov 2	1229	TT	D	12,200	637	191	63.5	92.6	Feb 2(92)	Jan 4(63)	Cosmic ray measurements.
Kosmos 95	88A	Nov 4	0531	KY	B-1		521	207	48.4	91.7	Jan 18(75)	Nov 28(24)	Military. Carrier rocket broke up.
Tyazheliy Sputnik	91B	Nov 12	0502	TT	A-2-e		283	217	51.9	89.5	Nov 25(13)	Nov 17(5)	Launched Venera 2.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Venera 2	91A					963	1.2 au	0.72 au	4.29	341D	solar orbit	solar orbit	Passed Venus at 24,000 Km, Feb 27. Communications failed.
Tyazheliy Sputnik	92B	Nov 16	0419	TT	A-2-e		286	203	51.9	89.3	Dec 3(17)	Nov 26(10)	Launched Venera 3.
Venera 3	92A					960	.99 au	0.7 au	4.29	290 D	Mar 1(105)	baryc orbit	Struck Venus 0656 Mar 1. Communications failed.
Kosmos 96	94A	Nov 23	0322	TT	A-2-e		310	227	51.9	89.6	Dec 9(16)	Dec 4(11)	Venus attempt failed to leave Earth orbit.
Venera	94A					960?							
Kosmos 97	95A	Nov 26	1214	KY	B-1		2,100	220	49.0	108.3	Apr 2(492)	Feb 21(452)	Maser and atomic clock.
Kosmos 98	97A	Nov 27	0824	TT	A-1		570	216	65.0	92.0	Dec 5(8)	Jan 23(57)	Observation. Probably recovered.
Tyazheliy Sputnik	99B	Dec 3	1048	TT	A-2-e		221	181	51.9	88.5	Dec 6(3)	Dec 5(2)	Launched Luna 8.
Luna 8	99A					1,552	---	---	---	---	Dec 6(3)	baryc orbit	Struck Moon at 9.1 N 63.3 W Dec 6.
Kosmos 99	103A	Dec 10	0810	TT	A-1		320	199	65.0	89.6	Dec 18(8)	Dec 28(18)	Observation. Probably recovered.
Kosmos 100	106A	Dec 17	0224	TT	A-1		650	650	65.0	97.7			Precursor to weather satellite.
Kosmos 101	107A	Dec 21	0614	KY	B-1		550	260	49.0	92.4	Jul 12(203)	Apr 16(116)	Military.
Kosmos 102	111A	Dec 27	2234	TT	A-1-m		278	218	65.0	89.2	Jan 13(17)	attached	Possibly maneuverable.
Kosmos 103	112A	Dec 28	1243	TT	C-1		600	600	56.0	97.0			Possible communications satellite.
	1966	1966											
Kosmos 104	1A	Jan 7	0824	TT	A-1		401	204	65.0	90.2	Jan 15(8)	Jan 24(17)	Observation. Probably recovered.
Kosmos 105	3A	Jan 22	0838	TT	A-1		324	204	65.0	89.7	Jan 30(8)	Feb 10(19)	Observation. Probably recovered.
Kosmos 106	4A	Jan 25	1229	KY	B-1		564	290	48.4	92.8	Nov 14(293)	Jul 16(172)	Military.
Tyazheliy Sputnik	6B	Jan 31	1146	TT	A-2-e		219	167	51.9	88.3	Feb 2(2)	Jan 31(0)	Launched Luna 9.
Luna 9	6A					1,583	---	---	---	---	Feb 3(3)	Baryc. orbit	Soft landed on Moon at 7.1 N, 64.3 W, Feb 3.

Kosmos 107	10A	Feb 10	0853	TT	A-1		322	204	65.0	89.7	Feb 18(8)	Feb 28(18)	Observation. Probably recovered.
Kosmos 108	11A	Feb 11	1800	KY	B-1		865	227	48.9	93.5	Nov 21(283)	Jun 1(110)	Upper atmosphere and solar activity.
Kosmos 109	14A	Feb 19	0853	TT	A-2		309	209	65.0	89.5	Feb 27(8)	Feb 27(8)	Observation. Probably recovered.
Kosmos 110	15A	Feb 22	2010	TT	A-2		904	187	51.9	96.3	Mar 16(23)	Apr 29(66)	Biological flight. Recovered.
Kosmos 111	17A	Mar 1	1102	TT	A-2-e		226	191	51.9	88.6	Mar 3(2)	Mar 1(0)	Moon attempt failed to leave Earth orbit.
Luna	17A					1,600?							
Kosmos 112	21A	Mar 17	1034	PL	A-1		565	214	72.0	92.1	Mar 25(8)	May 17(61)	Observation. Probably recovered. First Plesetsk launch.
Kosmos 113	23A	Mar 21	0936	TT	A-2		327	210	65.0	89.6	Mar 29(8)	Mar 30(9)	Observation. Probably recovered.
Tyazheliy Sputnik	27B	Mar 31	1048	TT	A-2-e		250	200	51.8	89.0	Apr 4(4)	Apr 2(2)	Launched Luna 10.
Luna 10	27A					1,600	1,017	350	71.9	178.3	lunar orbit	solar orbit	Payload in lunar orbit.
Kosmos 114	28A	Apr 6	1146	PL	A-2		374	210	73.0	90.1	Apr 14(8)	Apr 18(12)	Observation. Probably recovered.
Kosmos 115	33A	Apr 20	1048	TT	A-1		294	190	65.0	89.3	Apr 28(8)	Apr 30(10)	Observation. Probably recovered.
Tyazheliy Sputnik	35B	Apr 25	0712	TT	A-2-e		449	176	64.9	91.0	May 9(15)	May 8(14)	Launched Molniya 1-3.
Molniya 1-3	35A						39,500	499	64.5	710.0	Jun 11(2604)	Jun 18(2611)	Communications satellite.
Kosmos 116	36A	Apr 26	1005	KY	B-1		478	294	48.4	92.0	Dec 3(221)	Aug 15(111)	Military.
Kosmos 117	37A	May 6	1102	TT	A-1		308	207	65.0	89.5	May 14(8)	May 21(15)	Observation. Probably recovered.
Kosmos 118	38A	May 11	1410	TT	A-1		640	640	65.0	97.1			Precursor to weather satellite.
Kosmos 119	43A	May 24	0531	KY	B-1		1,305	219	48.5	99.8	Nov 30(190)	attached	Military.
Kosmos 120	50A	Jun 8	1102	TT	A-2		300	200	51.8	89.4	Jun 16(8)	Jun 12(4)	Observation. Probably recovered.
Kosmos 121	54A	Jun 17	1102	PL	A-2		354	210	72.9	89.9	Jun 25(8)	Jun 26(9)	Observation. Probably recovered.
Kosmos 122	57A	Jun 25	1019	TT	A-1		625	625	65.0	97.1			Weather satellite.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Proton 3	60A	Jul 6	1258	TT	D	12,200	630	190	63.5	92.5	Sep 16(72)	Aug 21(46)	Cosmic ray measurements.
Kosmos 123	61A	Jul 8	0531	KY	B-1		520	263	48.8	92.2	Dec 10(155)	Oct 2(86)	Military.
Kosmos 124	64A	Jul 14	1034	TT	A-2		303	208	51.8	89.4	Jul 22(8)	Jul 19(5)	Observation. Probably recovered.
Kosmos 125	67A	Jul 20	0907	TT	A-1-m		250	250	65.0	89.5	Aug 2(13)	attached	Possibly maneuverable.
Kosmos 126	68A	Jul 28	1048	TT	A-2		359	212	51.8	90.0	Aug 6(9)	Aug 10(13)	Observation. Probably recovered.
Kosmos 127	71A	Aug 8	1117	TT	A-2		279	204	51.9	89.2	Aug 16(8)	Aug 12(4)	Observation. Probably recovered.
Tyazheliy Sputnik	78C	Aug 24	0810	TT	A-2-e		201	193	51.8	88.4	Aug 26(2)	Aug 25(1)	Launched Luna 11.
Luna 11	78A					1,640	1,200	160	27.0	178.0	lunar orbit	baryc orbit	Payload in lunar orbit.
Kosmos 128	79A	Aug 27	0950	TT	A-2		364	212	65.0	90.0	Sep 4(8)	Sep 7(11)	Observation. Probably recovered.
Unannounced	88A	Sep 17	2234	TT	F-1-r		1,046	163	49.6	96.1	Nov 11(55)	Mar 4(168)	FOBS or maneuverable test. Probably failed.
Kosmos 129	91A	Oct 14	1214	PL	A-1		307	202	65.0	89.4	Oct 21(7)	Oct 23(9)	Observation. Probably recovered.
Tyazheliy Sputnik	92B	Oct 20	0755	TT	A-2-e		443	189	64.8	90.8	Nov 10(21)	Nov 2(13)	Launched Molniya 1-4.
Molniya 1-4	92A						39,700	485	64.9	713.0	Sep 11(692)	Jun 5(959)	Communications satellite.
Kosmos 130	93A	Oct 20	0853	TT	A-2		340	211	65.0	89.8	Oct 28(8)	Oct 29(9)	Observation. Probably recovered.
Tyazheliy Sputnik	94B	Oct 22	0838	TT	A-2-e		212	199	51.9	88.6	Oct 24(2)	Oct 23(1)	Launched Luna 12.
Luna 12	94A					1,670?	1,740	100	0.0	205.0	lunar orbit	baryc orbit	Payload in lurar orbit.
Unannounced	101A	Nov 2	0043	TT	F-1-r		855	140	49.6	94.5	Nov 17(15)	Nov 22(20)	FOBS or maneuverable test. Probably failed.
Kosmos 131	105A	Nov 12	0950	PL	A-2		360	205	72.9	89.9	Nov 20(8)	Nov 22(10)	Observation. Probably recovered.
Kosmos 132	106A	Nov 19	0810	TT	A-1		280	207	65.0	89.3	Nov 27(8)	Nov 27(8)	Observation. Probably recovered.

Kosmos 133	107A	Nov 28	1102	TT	A-2	6,400?	232	181	51.8	88.4	Nov 30(2)	Nov 29(1)	Precursor to manned. Probably recovered.
Kosmos 134	108A	Dec 3	0810	TT	A-2		319	214	65.0	89.6	Dec 11(8)	Dec 10(7)	Observation. Probably recovered.
Kosmos 135	112A	Dec 12	2038	KY	B-1		662	259	48.5	93.5	Apr 12(121)	Mar 15(93)	Micrometeorites gamma radiation.
Kosmos 136	115A	Dec 19	1200	PL	A-1		305	198	64.6	89.4	Dec 27(8)	Dec 28(9)	Observation. Probably recovered.
Tyazheliy Sputnik	116B	Dec 21	1019	TT	A-2-e		223	171	51.8	88.4	Dec 23(2)	Dec 22(1)	Launched Luna 13.
Luna 13	116A					1,670?	---	---	---	---	Dec 24(3)	baryc orbit	Soft landed on Moon Dec 24 18.9 N, 62.0 W.
Kosmos 137	117A	Dec 21	1312	KY	B-1		1,720	230	48.8	104.3	Nov 23(337)	Sep 25(278)	Radiation and particle studies.
	1967	1967											
Kosmos 138	4A	Jan 19	1243	PL	A-1		293	193	65.0	89.2	Jan 27(8)	Jan 28(9)	Observation. Probably recovered.
Kosmos 139	5A	Jan 25	1355	TT	F-1-r		210	144	50.0	87.5	Jan 25(0)	Jan 25(0)	FOBS test.
Kosmos 140	9A	Feb 7	0322	TT	A-2	6,400?	241	170	51.7	88.5	Feb 9(2)	Feb 8(1)	Precursor to manned. Probably recovered.
Kosmos 141	12A	Feb 8	1019	PL	A-2		345	210	72.9	89.8	Feb 16(8)	Feb 16(8)	Observation. Probably recovered.
Kosmos 142	1,3A	Feb 14	1005	KY	B-1		1,362	214	48.4	100.3	Jul 6(143)	Jun 15(121)	Radio propagation tests.
Kosmos 143	17A	Feb 27	0824	TT	A-1		302	204	65.0	89.5	Mar 7(8)	Mar 9(10)	Observation. Probably recovered.
Kosmos 144	18A	Feb 28	1438	PL	A-1		625	625	81.2	96.0			Weather satellite.
Kosmos 145	19A	Mar 3	0643	KY	B-1		2,135	220	48.4	108.6	Mar 8(371)	Dec 1(273)	Military.
Kosmos 146 Zond	21A 21C	Mar 10	1258	TT	D-1-e	4,820?	310 292	190 176	51.5 51.5	89.1 89.2	Mar 18(8)	Mar 19(9)	Precursor to Zond. Separated after 1 day. Major part disappeared.
Kosmos 147	22A	Mar 13	1214	PL	A-1		317	198	65.0	89.5	Mar 21(8)	Mar 22(9)	Observation. Probably recovered.
Kosmos 148	23A	Mar 16	1746	PL	B-1		436	275	71.0	91.3	May 7(52)	Apr 14(29)	Military.
Kosmos 149	24A	Mar 21	1005	KY	B-1		297	248	48.4	89.8	Apr 7(17)	Mar 24(3)	Experimental weather satellite.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Koamoa 150	25A	Mar 22	1243	PL	A-2		373	206	65.7	90.1	Mar 30(8)	Mar 30(8)	Observation. Probably recovered.
Kosmos 151	27A	Mar 24	1146	TT	C-1		630	630	56.0	97.1			Possible communications satellite.
Kosmos 152	28A	Mar 25	0658	PL	B-1		512	283	71.0	92.2	Aug 5(133)	May 22(58)	Military.
Kosmos 153	30A	Apr 4	1355	PL	A-1		291	202	64.6	89.3	Apr 12(8)	Apr 11(7)	Observation. Probably recovered.
Kosmos 154 Zond	32A 32A	Apr 8	0907	TT	D-1-e	4,820?	232	186	51.6	88.5	Apr 10(2)	attached	Precursor to Zond.
Kosmos 155	33A	Apr 12	1102	TT	A-2		296	203	51.8	89.2	Apr 20(8)	Apr 16(4)	Observation. Probably recovered.
Soyuz 1	37A	Apr 23	0043	TT	A-2	6,450	224	201	51.7	88.6	Apr 24(1)	Apr 24(1)	Komarov killed on reentry.
Kosmoa 156	39A	Apr 27	1243	PL	A-1		630	630	81.2	97.0			Weather satellite.
Kosmos 157	44A	May 12	1034	TT	A-1		296	202	51.3	89.4	May 20(8)	May 24(12)	Observation. Probably recovered.
Koamos 158	45A	May 15	1102	PL	C-1		850	850	74.0	100.6			Possible communications satellite.
Tyazheliy Sputnik	46C	May 17	2150	TT	A-2-e		395	208	51.7	90.5	Jun 2(16)	May 29(12)	Launched Kosmos 159.
Kosmos 159	46A						60,600	380	51.8	1177.0			Precursor test of manned ship or military early warning.
Koamos 160	47A	May 17	1605	TT	F-1-r		205	142	49.6	87.8	May 18(1)	May 18(1)	FOBS test.
Kosmos 161	49A	May 22	1355	PL	A-2		343	205	65.7	89.8	May 30(8)	May 28(6)	Observation. Probably recovered.
Tyazheliy. Sputnik	52C	May 24	2248	TT	A-2-e	472	203	64.9	91.3	Jun 15(22)		Jun 5(12)	Launched Molniya 1-5.
Molniya 1-5	52A						39,810	460	64.0	715.0	Nov 26(1647)	Dec 16(1667)	Communication satellite.
Kosmos 162	54A	Jun 1	1048	TT	A-2		280	201	51.8	89.2	Jun 9(8)	Jun 4(30)	Observation. Probably recovered.
Kosmoa 163	56A	Jun 5	0502	KY	B-1		616	261	48.4	93.1	Oct 11(128)	Sep 12(99)	Cosmic ray telescope.
Koamos 164	57A	Jun 8	1312	PL	A-2		320	202	65.7	89.5	Jun 14(6)	Jun 17(9)	Observation. Probably recovered.

Tyazheliy Sputnik	58B	Jun 12	0238	TT	A-2-e		188	162	51.8	87.9	Jun 13(1)	Jun 13(1)	Launched Venera 4.
Venera 4	58A					1,106	1.02 au	.65 au	2.0	283 D	Oct 18(126)	solar orbit	Probed atmosphere of Venus Oct 18.
Kosmos 165	59A	Jun 12	1814	PL	B-1		1,542	211	81.9	102.1	Jan 15(217)	Nov 1(142)	Military.
Kosmos 166	61A	Jun 16	0448	KY	B-1		578	283	48.4	92.9	Oct 25(131)	Oct 11(117)	Orbiting solar observatory.
Kosmos 167 (Venera)	63A	Jun 17	0238	TT	A-2-e	1,106?	286	201	51.8	89.2	Jun 25(8)	attached	Venus attempt failed to leave Earth orbit.
Tyazheliy Sputnik	63B						266	187	51.8	89.0	Jun 21(4)	Jun 26(9)	
Kosmos 168	67A	Jul 4	0600	TT	A-2		268	199	51.8	89.1	Jul 12(8)	Jul 8(4)	Observation. Probably recovered.
Kosmos 169	69A	Jul 17	1648	TT	F-1-r		208	144	50.0	87.6	Jul 17(0)	Jul 18(1)	FOBS test.
Kosmos 170	74A	Jul 31	1648	TT	F-1-r		208	145	50.0	87.9	Jul 31(0)	Aug 1(1)	FOBS test.
Kosmos 171	77A	Aug 8	1605	TT	F-1-r		220	145	50.0	87.6	Aug 8(0)	Aug 9(1)	FOBS test.
Kosmos 172	78A	Aug 9	0546	TT	A-2		301	202	51.8	89.4	Aug 17(8)	Aug 13(4)	Observation. Probably recovered.
Kosmos 173	81A	Aug 24	0502	PL	B-1		528	280	71.0	92.3	Dec 17(115)	Oct 30(67)	Military.
Tyazheliy Sputnik	82B	Aug 31	0755	TT	A-2-e		454	199	64.8	91.1	Sep 19(19)	Sep 15(15)	Launched Kosmos 174.
Kosmos 174	82A						39,750	500	64.5	715.0	Dec 30(487)	Jan 4(492)	Possible Molniya 1 failure, or early warning.
Kosmos 175	85A	Sep 11	1034	PL	A-2		386	210	72.9	92.2	Sep 19(8)	Sep 23(12)	Observation. Probably recovered.
Kosmos 176	86A	Sep 12	1702	PL	B-1		1,581	206	81.9	102.5	Mar 3(173)	Dec 12(91)	Military. Carrier rocket exploded.
Kosmos 177	88A	Sep 16	0600	TT	A-2		292	202	51.8	89.3	Sep 24(8)	Sep 19(3)	Observation. Probably recovered.
Kosmos 178	89A	Sep 19	1453	TT	F-1-r		205	145	50.0	87.8	Sep 19(0)	Sep 20(1)	FOBS test.
Kosmos 179	91A	Sep 22	1410	TT	F-1-r		208	145	50.0	87.9	Sep 22(0)	Sep 23(1)	FOBS test.
Kosmos 180	93A	Sep 26	1019	PL	A-2		370	212	72.9	90.1	Oct 4(8)	Oct 5(9)	Observation. Probably recovered.
Tyazheliy Sputnik	95B	Oct 3	0502	TT	A-2-e		441	200	64.8	91.0	Oct 17(14)	Oct 21(18)	Launched Molniya 1-6.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Molniya 1-6	95A						39,600	465	65.0	712.0	Mar 4(518)	Feb 10(497)	Communications satellite.
Kosmos 181	97A	Oct 11	1131	PL	A-2		344	200	65.6	89.7	Oct 19(8)	Oct 19(8)	Observation. Probably recovered.
Kosmos 182	98A	Oct 16	0755	TT	A-2		355	210	65.0	89.9	Oct 24(8)	Oct 24(8)	Observation. Probably recovered.
Kosmos 183	99A	Oct 18	1326	TT	F-1-r		212	145	50.0	87.9	Oct 18(0)	Oct 19(1)	FOBS test.
Tyazheliy Sputnik	101B	Oct 22	0838	TT	A-2-e		443	202	64.8	91.0	Nov 7(16)	Nov 3(12)	Launched Molniya 1-7.
Molniya 1-7	101A						39,740	456	64.7	714.0	Dec 31(801)	Jan 16(817)	Communications satellite.
Kosmos 184	102A	Oct 24	2302	PL	A-1		635	635	81.2	97.1			Weather satellite.
Kosmos 185	104A	Oct 27	0224	TT	F-1-m	first later	260 888	145 522	64.1	98.7	Jan 14(445)		Maneuverable. Interceptor test.
Kosmos 186	105A	Oct 27	0936	TT	A-2	6,530?	235	209	51.7	88.7	Oct 31(4)	Oct 29(2)	Precursor to manned. Docked with Kosmos 188. Recovered.
Kosmos 187	106A	Oct 28	1312	TT	F-1-r		210	145	50.0	87.8	Oct 28(0)	Oct 28(0)	FOBS test.
Kosmos 188	107A	Oct 30	0810	TT	A-2	6,530?	276	200	51.7	89.0	Nov 2(3)	Nov 2(3)	Precursor to manned. Docked with Kosmos 186. Recovered.
Kosmos 189	108A	Oct 30	1800	PL	C-1		600	535	74.0	95.7			Possible ferret satellite.
Kosmos 190	110A	Nov 3	1117	PL	A-2		347	201	65.7	89.8	Nov 11(8)	Nov 9(6)	Observation. Probably recovered.
Kosmos 191	115A	Nov 21	1424	PL	B-1		518	281	71.0	92.2	Mar 2(102)	Jan 14(54)	Military.
Kosmos 192	116A	Nov 23	1453	PL	C-1		760	760	74.0	99.9			Possible navigation satellite.
Kosmos 193	117A	Nov 25	1131	PL	A-2		354	203	65.7	89.9	Dec 3(8)	Dec 1(6)	Observation. Probably recovered.
Kosmos 194	119A	Dec 3	1200	PL	A-2		333	205	65.7	89.7	Dec 11(8)	Dec 9(6)	Observation. Probably recovered.
Kosmos 195	124A	Dec 16	1200	PL	A-2		375	211	65.7	90.1	Dec 24(8)	Dec 23(7)	Observation. Probably recovered.

Kosmos 196	125A	Dec 19	0620	KY	B-1		887	225	49.0	95.5	Jul 7(201)	Feb 20(63)	Upper atmospheric research.
Kosmos 197	126A	Dec 26	0907	KY	B-1		505	220	48.5	91.5	Jan 30(35)	Jan 8(13)	Military.
Kosmos 198	127A	Dec 27	1131	TT	F-1-m		first 281 later 952	265 894	65.1 65.2	89.8 103.4		Jan 21(25)	Maneuverable. Ocean surveillance test.
Kosmos 199	1968 3A	1968 Jan 16	1200	PL	A-2		386	204	65.7	90.2	Jan 24(8)	Feb 1(16)	Observation. Recovery failed, exploded.
Kosmos 200	6A	Jan 19	2205	PL	C-1		536	536	74.0	95.2		Feb 4(1477)	Possible ferret satellite.
Kosmos 201	9A	Feb 6	0755	TT	A-2		355	210	65.0	89.9	Feb 14(8)	Feb 13(7)	Observation. Probably recovered.
Kosmos 202	10A	Feb 20	1005	KY	B-1		502	220	48.4	91.5	Mar 24(33)	Mar 4(13)	Military.
Kosmos 203	11A	Feb 20	1605	PL	C-1		1,200	1,200	74.1	100.4			Possible navigation/geodetic satellite.
Tyazheliy Sputnik	13B	Mar 2	1829	TT	D-1-e		206	190	51.5	88.4	Mar 7(2)	Mar 7(2)	Launched Zond 4.
Zond 4	13A					4,820	Launched toward 'simulated' Moon.				Mar 9(7)	unknown	Probable systems test for circumlunar vehicle.
Kosmos 204	15A	Mar 5	1117	PL	B-1		873	282	71.0	95.0	Mar 2(362)	Oct 13(222)	Military.
Kosmos 205	16A	Mar 5	1220	PL	A-2		310	201	65.7	89.4	Mar 13(8)	Mar 9(4)	Observation. Probably recovered.
Kosmos 206	19A	Mar 14	0936	PL	A-1		630	630	81.0	97.0			Weather satellite.
Kosmos 207	21A	Mar 16	1229	PL	A-2		342	210	65.6	89.8	Mar 24(8)	Mar 22(6)	Observation. Probably recovered.
Kosmos 208	22A	Mar 21	0950	TT	A-2		305	207	65.0	89.4	Apr 2(12)	Mar 25(4)	Observation. Probably recovered. Separated a capsule. Studied high energy gamma fluxes.
Kosmos 209	23A	Mar 22	0936	TT	F-1-m		first 282 later 944	250 871	65.1 65.3	89.6 103.1	Mar 4(347)	Mar 25(3)	Maneuverable. Ocean surveillance test.
Kosmos 210	24A	Apr 3	1102	PL	A-2		395	217	81.2	90.3	Apr 11(8)	Apr 12(9)	Observation. Probably recovered.
Tyazheliy Sputnik	27B	Apr 7	1005	TT	A-2-e		242	189	51.8	88.8	Apr 9(2)	Apr 9(2)	Launched Luna 14.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Luna 14	27A					1,670?	870	160	42.0	160.0	lunar orbit unknown		Payload in lunar orbit.
Kosmos 211	28A	Apr 9	1131	PL	B-1		1,574	210	81.9	102.5	Nov. 10(215)	Aug 17(130)	Military.
Kosmos 212	29A	Apr 14	1005	TT	A-2	6,530?	239	210	51.7	88.8	Apr 19(5)	Apr 16(2)	Precursor to manned. Docked with Kosmos 213. Recovered.
Kosmos 213	30A	Apr 15	0936	TT	A-2	6,530?	291	205	51.4	89.2	Apr 20(5)	Apr 19(4)	Precursor to manned. Docked with Kosmos 212. Recovered.
Kosmos 214	32A	Apr 18	1034	PL	A-2		403	211	81.4	90.3	Apr 26(8)	Apr 25(7)	Observation. Probably recovered.
Kosmos 215	33A	Apr 18	2234	KY	B-1		426	261	48.5	91.1	Jun 30(73)	May 19(31)	Astronomical observatory.
Kosmos 216	34A	Apr 20	1034	TT	A-2		277	199	51.8	89.1	Apr 28(8)	Apr 23(3)	Observation. Probably recovered.
Tyazheliy Sputnik	35B	Apr 21	0419	TT	A-2-e		391	231	65.0	90.7	May 11(20)	May 29(38)	Launched Molniya 1-8.
Molniya 1-8	35A						39,700	460	65.0	713.0	Jan 29(2109)	Jul 9(2270)	Communications satellite.
Kosmos 217	36A	Apr 24	1605	TT	F-1-m	announced actual	520 262	396 144	62.2 62.2	93.4 88.5	Apr 26(2)	none	Maneuverable. Interceptor target.
Kosmos 218	37A	Apr 25	0043	TT	F-1-r		210	144	50.0	87.8	Apr 25(0)	Apr 25(0)	FOBS test.
Kosmos 219	38A	Apr 26	0448	KY	B-1		1,770	222	48.4	104.7	Mar 2(310)	Feb 24(304)	Charged particle studies.
Kosmos 220	40A	May 7	1355	PL	C-1		760	670	74.0	99.2			Possible navigation satellite.
Kosmos 221	43A	May 24	0712	KY	B-1		2,108	220	48.4	108.3	Aug 31(457)	Apr 13(324)	Military.
Kosmos 222	44A	May 30	2024	PL	B-1		528	277	71.0	92.3	Oct 11(134)	Aug 13(75)	Military.
Kosmos 223	45A	Jun 1	1102	PL	A-2		374	212	72.9	90.1	Jun 9(8)	Jun 9(8)	Observation. Recovered.
Kosmos 224	46A	Jun 4	0643	TT	A-2		270	200	51.8	89.0	Jun 12(8)	Jun 7(3)	Observation. Probably recovered. Also measured atmosphere composition.
Kosmos 225	48A	Jun 11	2136	KY	B-1		530	257	48.4	92.2	Nov 2(144)	Aug 15(65)	Electron flux, cosmic rays.

Kosmos 226	49A	Jun 12	1312	PL	A-1		650	603	81.2	96.9			Weather satellite.
Kosmos 227	51A	Jun 18	0614	TT	A-2		281	194	51.8	89.1	Jun 26(8)	Jun 21(3)	Observation. Probably recovered.
Kosmos 228	53A	Jun 21	1200	TT	A-2		259	206	51.6	89.0	Jul 3(12)	Jun 24(3)	Observation. Probably recovered. Separated a capsule for cosmic ray studies.
Kosmos 229	54A	Jun 26	1102	PL	A-2		354	210	72.8	88.9	Jul 4(8)	Jul 4(8)	Observation. Probably recovered.
Kosmos 230	56A	Jul 5	0658	KY	B-1		580	290	48.5	93.0	Nov 2(120)	Oct 16(103)	Orbiting solar observatory.
Tyazheliy Sputnik	57B	Jul 6	1522	TT	A-2-e		449	234	65.0	91.4	Aug 22(48)	Aug 9(35)	Launched Molniya 1-9.
Molniya 1-9	57A						39,700	470	65.0	715.0	May 15(1043)	Sep 2(788)	Communications satellite.
Kosmos 231	58A	Jul 10	1955	TT	A-2		330	211	65.0	89.7	Jul 18(8)	Jul 20(10)	Observation. Probably recovered.
Kosmos 232	60A	Jul 16	1312	PL	A-2		352	202	65.0	89.8	Jul 24(8)	Jul 26(10)	Observation. Probably recovered.
Kosmos 233	61A	Jul 18	1955	PL	B-1		1,545	210	82.0	102.1	Feb 7(204)	Jan 1(167)	Military.
Kosmos 234	62A	Jul 30	0658	TT	A-2		310	210	51.8	89.5	Aug 5(6)	Aug 7(8)	Observation. Probably recovered.
Kosmos 235	67A	Aug 9	0658	TT	A-2		303	207	51.8	89.4	Aug 17(8)	Aug 14(5)	Observation. Probably recovered.
Kosmos 236	70A	Aug 27	1131	TT	C-1		655	600	56.0	96.9			Possible communications satellite.
Kosmos 237	71A	Aug 27	1229	PL	A-2		343	201	65.4	89.7	Sep 4(8)	Sep 4(8)	Observation. Probably recovered.
Kosmos 238	72A	Aug 28	1005	TT	A-2	6,530?	219	199	51.7	88.5	Sep 1(4)	Aug 30(2)	Precursor to manned. Probably recovered.
Kosmos 239	73A	Sep 5	0658	TT	A-2		282	202	51.8	89.2	Sep 13(8)	Sep 9(4)	Observation. Probably recovered.
Kosmos 240	75A	Sep 14	0643	TT	A-2		293	197	51.8	89.3	Sep 21(7)	Sep 17(3)	Observation. Probably recovered.
Tyazheliy Sputnik	76B	Sep 14	2136	TT	D-1-e		219	187	51.3	88.4	Sep 16(2)	Sep 18(4)	Launched Zond 5.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Zond 5	76					4,820					Sep 21(7)	unknown	Circumlunar vehicle. Recovered.
Kosmos 241	77A	Sep 16	1229	PL	A-2		343	201	65.4	89.7	Sep 24(8)	Sep 22(6)	Observation. Probably recovered.
Kosmos 242	79A	Sep 20	1438	PL	B-1		440	280	71.0	91.3	Nov 13(54)	Oct 22(32)	Military.
Kosmos 243	80A	Sep 23	0741	TT	A-2		319	210	71.3	89.6	Oct 4(11)	Sep 29(6)	Observation. Probably recovered. Separated capsule with radio-telescope for passive microwave.
Kosmos 244	82A	Oct 2	1341	TT	F-1-r		212	140	50.0	87.5	Oct 2(0)	Oct 2(0)	FOBS test.
Kosmos 245	83A	Oct 3	1258	PL	B-1		509	282	71.0	92.1	Jan 15(104)	Nov 16(44)	Military.
Tyazheliy Sputnik	85C	Oct 5	0029	TT	A-2-e		466	224	65.0	91.4	Nov 4(30)	Oct 30(25)	Launched Molniya 1-10.
Molniya 1-10	85A						39,600	490	65.0	712		May 7(2405)	Communications satellite.
Kosmos 246	87A	Oct 7	1214	PL	A-2		348	147	65.4	89.4	Oct 12(5)	Oct 8(1)	Observation. Probably recovered.
Kosmos 247	88A	Oct 11	1200	PL	A-2		362	205	65.4	89.9	Oct 19(8)	Oct 18(7)	Observation. Probably recovered.
Kosmos 248	90A	Oct 19	0418	TT	F-1-m		551	490	62.3	94.8		Dec 28(70)	Maneuverable target for intercept.
Kosmos 249	91A	Oct 20	0405	TT	F-1-m		2,177	514	62.4	112.2		Oct 21(1)	Maneuverable interceptor. Near pass on 248. Exploded.
Soyuz 2	93A	Oct 25	0907	TT	A-2	6,530?	224	185	51.7	88.5	Oct 28(3)	Oct 27(2)	Precursor to manned and rendezvous target. Recovered.
Soyuz 3	94A	Oct 26	0838	TT	A-2	6,575	225	205	51.7	88.6	Oct 30(4)	Oct 28(2)	Beregovoy. Did rendezvous on Soyuz 2. Recovered.
Kosmos 250	95A	Oct 31	2205	PL	C-1		556	523	74.0	95.3			Possible ferret satellite.
Kosmos 251	96A	Oct 31	0907	TT	A-2		270	198	65.0	89.1	Nov 12(12)	Nov 2(2)	Observation. Probably recovered. Separated a module. Radio astronomy gamma ray experiment.
Kosmos 252	97A	Nov 1	0029	TT	F-1-m		2,172	538	61.9	112.5			Maneuverable interceptor. Near pass on 248. Exploded.

Tyazheliy Sputnik	101B	Nov 10	1912	TT	D-1-e		210	185	51.4	87.9	Nov 12(2)	Nov 13(3)	Launched Zond 6.
Zond 6	101A					4,820					Nov 17(7)	unknown	Circumlunar vehicle. Recovered.
Kosmos 253	102A	Nov. 13	1200	PL	A-2		355	206	65.4	89.9	Nov 18(5)	Nov 20(7)	Observation. Probably recovered.
Proton 4	103A	Nov 16	1146	TT	D-1	17,000	495	255	51.5	91.8	Jul 24(250)	Jan 25(70)	Cosmic ray measurements.
Kosmos 254	104A	Nov 21	1214	PL	A-2		350	203	65.4	89.8	Nov 29(8)	Nov 27(6)	Observation. Probably recovered.
Kosmos 255	105A	Nov 29	1243	PL	A-2		336	201	65.4	89.7	Dec 7(8)	Dec 5(6)	Observation. Probably recovered.
Kosmos 256	106A	Nov 30	1200	PL	C-1		1,234	1,168	74.1	109.3			Possible navigation/geodetic satellite.
Kosmos 257	107A	Dec 3	1453	PL	B-1		470	282	71.0	91.1	Mar 5(92)	Jan 16(44)	Military.
Kosmos 258	111A	Dec 10	0824	TT	A-2		325	210	65.0	89.6	Dec 18(8)	Dec 17(7)	Observation. Probably recovered.
Kosmos 259	113A	Dec 14	0517	KY	B-1		1,353	219	48.5	100.3	May 5(142)	May 10(147)	Radio propagation tests.
Tyazheliy Sputnik	115B	Dec 16	0922	TT	A-2-e		510	240	64.9	92.0	Jan 18(33)	Feb 6(52)	Launched Kosmos 260.
Kosmos 260	115A						39,600	500	65.0	712.0	Jul 9(1666)	Sep 21(1740)	Possibly a Molniya comsat failure or early warning.
Kosmos 261	117A	Dec 19	1155	PL	B-1		670	217	71.0	93.1	Feb 12(55)	Jan 7(18)	Upper atmosphere and polar aurorae studies. Carrier rocket exploded.
Kosmos 262	119 A	Dec 26	0950	KY	B-1		818	263	48.5	95.2	Jul 18(204)	Apr 20(125)	Hard radiation intensity.
Tyazheliy Sputnik	1969 1C	1969 Jan 5	0629	TT	A-2-e		225	186	51.8	88.6	Jan 7(2)	Jan 6(1)	Launched Venera 5.
Venera 5	1A					1,130					May 16(131)	solar orbit	Probed atmosphere of Venus May 16.
Tyazheliy Sputnik	2C	Jan 10	0546	TT	A-2-e		207	.201	51.7	88.5	Jan 13(3)	Jan 11(1)	Launched Venera 6
Venera 6	2A					1,130					May 17(127)	solar orbit	Probed atmosphere of Venus May 17.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Kosmos 263	3A	Jan 12	1214	PL	A-2		346	205	65.4	89.8	Jan 20(8)	Jan 18(6)	Observation. Probably recovered.
Soyuz 4	4A	Jan 14	0726	TT	A-2	6,625	225	173	51.7	88.3	Jan 17(3)	Jan 15(1)	Shatalov. Docking target for Soyuz 5. Returned also Yeliseyev, Khrunov.
						(12,924 combined Soyuz 4 and 5)							
Soyuz 5	5A	Jan 15	0658	TT	A-2	6,585	230	200	51.7	88.7	Jan 18(3)	Jan 17(2)	Volynov. Docked with Soyuz 4. Transferred Yeliseyev, Khrunov. Recovered.
Kosmos 264	8A	Jan 23	0922	TT	A-2		330	219	70.0	89.7	Feb 5(13)	Jan 30(7)	Observation. Probably recovered. Separated a module. Radio astronomy gamma ray experiment. sule.
Kosmos 265	12A	Feb 7	1410	PL	B-1		485	283	71.0	91.9	May 1(83)	Mar 17(38)	Military.
Kosmos 266	15A	Feb 25	1019	PL	A-2		358	208	72.9	89.9	Mar 5(8)	Mar 4(7)	Observation. Probably recovered.
Kosmos 267	17A	Feb 26	0824	TT	A-2		346	210	65.0	89.9	Mar 6(8)	Mar 5(7)	Observation. Probably recovered.
Kosmos 268	20A	Mar 5	1312	KY	B-1		2,186	219	48.4	109.2	May 9(430)	Feb 11(343)	Military.
Kosmos 269	21A	Mar 5	1731	PL	C-1		558	526	74.0	95.3			Possible ferret satellite.
Kosmos 270	22A	Mar 6	1214	PL	A-2		350	205	65.4	89.8	Mar 14(8)	Mar 12(6)	Observation. Recovered.
Kosmos 271	23A	Mar 15	1214	PL	A-2		342	200	65.4	89.7	Mar 23(8)	Mar 22(6)	Observation. Probably recovered.
Kosmos 272	24A	Mar 17	1648	PL	C-1		1,220	1,195	74.0	109.4			Possible navigation/geodetic satellite.
Kosmos 273	27A	Mar 22	1214	PL	A-2		356	205	65.4	89.9	Mar 30(8)	Mar 28(6)	Observation. Probably recovered.
Kosmos 274	28A	Mar 24	1005	TT	A-2		323	213	65.0	89.6	Apr 1(8)	Mar 29(5)	Observation. Probably recovered.
Meteor 1	29A	Mar 26	1229	PL	A-1		713	644	81.2	97.0			Weather satellite.
Kosmos 275	31A	Mar 28	1605	PL	B-1		805	284	71.0	95.2	Feb 7(316)	Sep 16(170)	Military.

Kosmos 276	32A	Apr 4	1019	PL	A-2		410	214	81.4	90.4	Apr 11(7)	Apr 14(10)	Observation. Probably recovered.
Kosmos 277	33A	Apr 4	1258	PL	B-1		494	280	71.0	92.0	Jul 6(93)	May 18(44)	Military.
Kosmos 278	34A	Apr 9	1258	PL	A-2		338	203	65.0	89.7	Apr 17(8)	Apr 16(7)	Observation. Probably recovered.
Tyazheliy Sputnik	35D	Apr 11	0238	TT	A-2-e		461	222	65.0	91.4	May 5(24)	May 1(16)	Launched Molniya 1-11.
Molniya 1-11	35A						39,700	470	65.0	713.0			Communications satellite.
Kosmos 279	38A	Apr 15	0824	TT	A-2		280	194	51.8	89.1	Apr 23(8)	Apr 18(3)	Observation. Probably recovered.
Kosmos 280	40A	Apr 23	1005	TT	A-2		272	206	51.6	89.1	May 6(13)	Apr 26(3)	Observation. Probably recovered. Weather studies. Separated a module.
Kosmos 281	42A	May 13	0922	PL	A-2		317	194	65.4	89.4	May 21(8)	May 17(4)	Observation. Recovered.
Kosmos 282	44A	May 20	0838	PL	A-2		343	209	65.4	89.8	May 28(8)	May 28(8)	Observation. Probably recovered.
Kosmos 283	47A	May 27	1258	PL	B-1		1,539	210	82.0	102.1	Dec 10(197)	Oct 1(127)	Military.
Kosmos 284	48A	May 29	0658	TT	A-2		308	207	51.8	89.5	Jun 6(8)	Jun 4(6)	Observation. Probably recovered.
Kosmos 285	49A	Jun 3	1258	PL	B-1		518	279	71.0	92.2	Oct 7(126)	Aug 5(63)	Military.
Kosmos 286	52A	Jun 15	0907	PL	A-2		349	206	65.4	89.8	Jun 23(8)	Jun 23(8)	Observation. Probably recovered.
Kosmos 287	54A	Jun 24	0658	TT	A-2		268	190	51.8	89.0	Jul 2(8)	Jun 27(3)	Observation. Recovered.
Kosmos 288	55A	Jun 27	0712	TT	A-2		281	201	51.8	89.2	Jul 5(8)	Jul 2(5)	Observation. Probably recovered.
Kosmos 289	57A	Jul 10	0907	PL	A-2		350	200	65.4	89.8	Jul 15(5)	Jul 16(6)	Observation. Probably recovered.
Tyazheliy Sputnik	58B	Jul 13	0307	TT	D-1-e		247	182	51.6	88.7	Jul 16(3)	Jul 16(3)	Launched Luna 15.
Luna 15	58A	-				4,820?	110	16	127	114.0	Jul 21(8)	unknown	Maneuvered several times, but failed in soft landing attempt on Moon.
Kosmos 290	60A	Jul 22	1229	PL	A-2		352	200	65.4	89.8	Jul 30(8)	Jul 29(7)	Observation. Probably recovered.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Tyazheliy Sputnik	61B	Jul 22	1258	TT	A-2-e		492	228	64.9	91.7	Aug 23(32)	Aug 28(37)	Launched Molniya 1-12.
Molniya 1-12	61A						39,540	520	64.9	711.0	Jun 18(696)	Jun 10(688)	Communications satellite.
Kosmos 291	66A	Aug 6	0546	TT	F-1-m		574	153	623	91.5	Sep 8(33)	Aug 11(5)	Maneuverable. Target for Interception.
Tyazheliy Sputnik	67B	Aug 7	2355	TT	D-1-e		191	183	51.5	88.2	Aug 10(3)	Aug 12(5)	Launched Zond 7.
Zond 7	67A					4,820?					Aug 14(7)	unknown	Circumlunar vehicle. Recovered.
Kosmos 292	70A	Aug 13	2205	PL	C-1		786	747	74.0	99.9			Possible navigation satellite.
Kosmos 293	71A	Aug 16	1200	TT	A-2		270	208	51.8	89.1	Aug 28(12)	Aug 20(4)	Observation. Probably recovered.
Kosmos 294	72A	Aug 19	1258	PL	A-2		343	202	65.4	89.8	Aug 27(8)	Aug 27(8)	Observation. Probably recovered.
Kosmos 295	73A	Aug 22	1424	PL	B-1		500	282	71.0	92.0	Dec 1(101)	Oct 11(50)	Military.
Kosmos 296	75A	Aug 29	0907	TT	A-2		322	211	65.0	89.6	Sep 6(8)	Sep 5(7)	Observation. Probably recovered.
Kosmos 297	76A	Sep 2	1102	PL	A-2		334	211	72.9	89.7	Sep 10(8)	Sep 11(9)	Observation. Probably recovered.
Kosmos 298	77A	Sep 15	1424	TT	F-1-r		212	140	50	87.3	Sep 15(0)	Sep 16(1)	FOBS test.
Kosmos 299	78A	Sep 18	0838	TT	A-2		311	214	65.0	89.5	Sep 22(4)	Sep 24(6)	Observation. Probably recovered.
Kosmos 300 Luna	80A 80A	Sep 23	1410	TT	D-1-e	4,820?	208	190	51.5	88.2	Sep 27(4)	Sep 27(4)	Probably lunar attempt. Failed to leave Earth orbit.
Kosmos 301	81A	Sep 24	1214	PL	A-2		307	197	65.4	89.4	Oct 2(8)	Sep 29(5)	Observation. Probably recovered.
Meteor 2	84A	Oct 6	0141	PL	A-1		690	630	81.2	97.7			Weather satellite.
Soyuz 6	85A	Oct 11	1117	TT	A-2	6,577	223	186	51.7	88.4	Oct 16(5)	Oct 12(1)	Shonin, Kubasov. Near rendezvous. Recovered.

Soyuz 7	86A	Oct 12	1043	TT	A-2	6,570	226	207	51.7	88.6	Oct 17(5)	Oct 14(2)	Filipchenko, Volkov, Gorbatko. Target for rendezvous . Recovered.
Soyuz 8	87A	Oct 13	1034	TT	A-2	6,646	223	205	51.7	88.6	Oct 18(5)	Oct 15(2)	Shatalov, Yeliseyev. Near rendezvous. Recovered.
Interkosmos 1	88A	Oct 14	1341	KY	B-1		640	260	48.4	93.3	Jan 2(80)	Dec 16(63)	Soviet bloc science. solar and upper atmospheric studies.
Kosmos 302	89A	Oct 17	1146	PL	A-2		340	202	65.4	89.7	Oct 25(8)	Oct 24(7)	Observation. Probably recovered.
Kosmos 303	90A	Oct 18	1005	PL	B-1		492	282	71.0	91.9	Jan 23(97)	Dec 7(50)	Military.
Kosmos 304	91A	Oct 21	1258	PL	C-1		774	747	74.0	99.9			Possible navigation satellite.
Kosmos 305 Luna	92A 92A	Oct 22	1410	TT	D-1-e	4,820?	205	193	51.5	88.2	Oct 24(2)	Oct 24(2)	Probable lunar attempt failed to leave Earth orbit.
Kosmos 306	93A	Oct 24	0950	TT	A-2		332	208	65.0	89.7	Nov 5(12)	Oct 29(5)	Observation. Probably recovered.
Kosmos 307	94A	Oct 24	1312	KY	B-1		2,178	220	48.4	109.1	Dec 30(432)	Jul 20(269)	Military.
Kosmos 308	96A	Nov 4	1200	PL	B-1		422	281	71.0	91.3	Jan 4(61)	Dec 6(32)	Military.
Kosmos 309	98A	Nov 12	1131	PL	A-2		384	203	65.4	90.1	Nov 20(8)	Nov 22(10)	Observation. Probably recovered. Separated a capsule.
Kosmos 310	100A	Nov 15	0838	TT	A-2		347	208	65.0	89.8	Nov 23(8)	Nov 23(8)	Observation. Probably recovered.
Kosmos 311	102A	Nov 24	1102	PL	B-1		496	284	71.0	92.0	Mar 10(106)	Jan 19(56)	Military.
Kosmos 312	103A	Nov 24	1648	PL	C-1		1,187	1,145	74.0	108.6			Possible navigation/geodetic satellite.
Kosmos 313	104A	Dec 3	1326	PL	A-2		276	204	65.4	89.1	Dec 15(12)	Dec 6(3)	Observation. Probably recovered.
Kosmos 314	106A	Dec 11	1258	PL	B-1		491	282	71.0	91.9	Mar 22(101)	Jan 27(47)	Military.
Kosmos 315	107A	Dec 20	0336	PL	C-1		556	521	74.0	95.3			Possible ferret satellite.
Kosmos 316	108A	Dec 23	0922	TT	F-1-m		1,650	154	49.5	102.7	Aug 28(248)	Jan 1(9)	Maneuverable. Possibly related to FOBS.
Kosmos 317	109A	Dec 23	1355	PL	A-2		302	209	65.4	89.4	Jan 5(13)	Dec 28(5)	Observation. Probably recovered. Separated a module. Also did charged-particle studies.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Interkosmos 2	110A	Dec 25	1005	KY	B-1		1,200	206	48.4	98.5	Jun 7(164)	Mar 21(86)	Soviet bloc science. Ionosphere and magnetosphere.
	1970	1970											
Kosmos 318	1A	Jan 9	0922	TT	A-2		295	204	65.0	89.3	Jan 21(12)	Jan 15(6)	Observation. Probably recovered.
Kosmos 319	4A	Jan 15	1341	PL	B-1		1,537	209	82.0	102.0	Jul 1(167)	May 1(106)	Military.
Kosmos 320	5A	Jan 16	1102	KY	B-1		342	240	48.5	90.0	Feb 10(25)	Jan 28(12)	Experimental weather satellite.
Kosmos 321	6A	Jan 20	2024	PL	B-1		507	289	71.0	92.0	Mar 23(62)	Mar 7(46)	Ionosphere and geomagnetic studies.
Kosmos 322	7A	Jan 21	1200	PL	A-2		337	200	65.4	89.7	Jan 29(8)	Jan 25(4)	Observation. Probably recovered.
Kosmos 323	10A	Feb 10	1200	PL	A-2		333	206	65.4	89.7	Feb 18(8)	Feb 15(5)	Observation. Probably recovered.
Tyazheliy Sputnik	13B	Feb 19	1858	PL	A-2-e		485	205	65.4	91.4	Mar 9(18)	Mar 11(20)	Launched Molniya 1-13.
Molniya 1-13	13A						39,175	487	65.3	703.0	Sep 29(2048)		Communications satellite.
Kosmos 324	14A	Feb 27	1731	PL	B-1		492	283	71.0	92.0	May 23(54)	Apr 11(46)	Military.
Kosmos 325	15A	Mar 4	1214	PL	A-2		348	207	65.4	89.8	Mar 12(8)	Mar 10(6)	Observation. Probably recovered.
Kosmos 326	18A	Mar 13	0755	PL	A-2		393	212	81.4	90.2	Mar 21(8)	Mar 23(10)	Observation. Probably recovered.
Meteor 3	19A	Mar 17	1117	PL	A-1		643	555	81.2	96.4			Weather satellite.
Kosmos 327	20A	Mar 19	1438	PL	B-1		855	279	71.0	95.6	Jan 19(316)	Sep 27(192)	Military.
Kosmos 328	22A	Mar 27	1146	PL	A-2		340	213	72.9	89.7	Apr 9(13)	Apr 1(5)	Observation. Probably recovered. Maneuvered, but no separated module.
Kosmos 329	23A	Apr 3	0838	PL	A-2		240	202	81.3	88.8	Apr 15(12)	Apr 5(2)	Observation. Probably recovered.
Kosmos 330	24A	Apr 7	1117	PL	C-1		548	514	74.1	95.2			Possible ferret satellite.

Kosmos 331	26A	Apr 8	1019	TT	A-2		347	213	65	89.9	Apr 16(8)	Apr 16(8)	Observation. Probably recovered.
Kosmos 332	28A	Apr 11	1702	PL	C-1		786	775	74.5	100			Possible navigation satellite.
Kosmos 333	30A	Apr 15	0907	PL	A-2		265	217	81.4	89.1	Apr 28(13)	Apr 18(3)	Observation. Probably recovered. Separated a module.
Kosmos 334	33A	Apr 23	1326	PL	B-1		508	281	71	92.1	Aug 9(108)	May 16(23)	Military.
Kosmos 335	35A	Apr 24	2234	KY	B-1		415	254	48.7	91	Jun 22(59)	May 17(23)	UV Radiation.
Kosmos 336	36A	Apr 25	1702	PL	C-1		1,500	1,400	74	115			Octuple launch. Possible communications satellites.
Kosmos 337	36B						1,500	1,400	74	115			
Kosmos 338	36C						1,500	1,400	74	115			
Kosmos 339	36D						1,500	1,400	74	115			
Kosmos 340	36E						1,500	1,400	74	115			
Kosmos 341	36F						1,500	1,400	74	115			
Kosmos 342	36G						1,500	1,400	74	115			
Kosmos 343	36H						1,500	1,400	74	115			
Meteor 4	37A	Apr 28	1048	PL	A-1		736	637	81.2	98.1			Weather satellite.
Kosmos 344	38A	May 12	1019	PL	A-2		347	206	72.9	89.8	May 20(8)	May 20(8)	Observation. Probably recovered.
Kosmos 345	39A	May 20	0922	TT	A-2		276	193	51.8	89.1	May 28(8)	May 23(3)	Observation. Probably recovered.
Soyuz 9	41A	Jun 1	1858	TT	A-2	6,500	first 220 later 266	207 247	51.7 51.7	88.6 89.5	Jun 19(18)	Jun 3(20)	Nikolayev. Sevastyanov. Recovered.
Kosmos 346	42A	Jun 10	0936	TT	A-2		289	201	51.8	89.3	Jun 17(7)	Jun 13(3)	Observation. Probably recovered.
Kosmos 347	43A	Jun 12	0936	KY	B-1		2,073	223	48.4	108	Nov 7(513)	Feb 14(247)	Military.
Kosmos 348	44A	Jun 13	0502	PL	B-1		680	212	71	93	Jul 25(42)	Jul 9(26)	Science with Bloc countries. Atmospheric and auroral studies.
Kosmos 349	45A	Jun 17	1258	PL	A-2		350	203	65.4	89.8	Jun 25(8)	Jun 22(5)	Observation. Probably recovered.
Meteor 5	47A	Jun 23	1424	PL	A-1		906	863	81.2	102			Weather satellite.
Tyazheliy Sputnik	49B	Jun 26	0322	PL	A-2-e		462	225	65.4	91.4	Jul 25(29)	Jul 17(21)	Launched Molniya 1-14.
Molniya 1-14	49A						39,280	470	65	705			Communications satellite.
Kosmos 350	50A	Jun 26	1200	TT	A-2		267	204	51.8	89.1	Jul 8(12)	Jun 29(3)	Observation. Probably recovered.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Kosmos 351	51A	Jun 27	0741	PL	B-1		494	282	71	92	Oct 13(108)	Aug 18(52)	Military.
Kosmos 352	52A	Jul 7	1034	TT	A-2		309	205	51.8	89.5	Jul 15(8)	Jul 12(5)	Observation. Probably recovered.
Kosmos 353	53A	Jul 9	1341	PL	A-2		309	211	65.4	89.4	Jul 21(12)	Jul 16(7)	Observation. Probably recovered.
Kosmos 354	56A	Jul 28	2205	TT	F-1-r		208	144	50		Jul 28(0)	Jul 29(1)	FOBS test.
Inter-kosmos 3	57A	Aug 7	0307	KY	B-1		1,320	207	49	99.8	Dec 6(121)	Nov 17(102)	Soviet bloc science. Cosmic rays and charged particles.
Kosmos 355	58A	Aug 7	0936	PL	A-2		342	202	66.4	89.7	Aug 15(8)	Aug 14(7)	Observation. Probably recovered.
Kosmos 356	59A	Aug 10	2010	PL	B-1		600	240	82	92.6	Oct 2(53)	Oct 1(52)	Atmospheric and auroral studies.
Tyazheliy Sputnik	60C	Aug 17	0538	TT	A-2-e		233	174	51.7	88.5	Aug 18(1)	Aug 18(1)	Launched Venera 7.
Venera 7	60A					1,180					Dec 15(120)	solar orbit	Landed on Venus.
Kosmos 357	63A	Aug 19	1507	PL	B-1		500	282	71	92	Nov 24(97)	Oct 15(57)	Military.
Kosmos 358	64A	Aug 21	1438	PL	C-1		549	517	74	95.2			Possible ferret satellite.
Tyazheliy Sputnik	65C	Aug 22	0517	TT	A-2-e		890	207	51.2	95.6	Sep 11(20)	Aug 29(7)	Launched Kosmos 359.
Kosmos 359 Venera	65A					1,180?	910	210	51.5	95.5	Nov 6(76)	Oct 6(45)	Venera failure, Earth orbit only.
Kosmos 360	68A	Aug 29	0838	TT	A-2		318	209	65	89.5	Sep 8(10)	Sep 2(4)	Observation. Probably recovered. Separated a capsule.
Kosmos 361	71A	Sep 8	1034	PL	A-2		326	207	72.9	89.6	Sep 21(13)	Sep 14(6)	Observation. Probably recovered. Separated a module.
Tyazheliy Sputnik	72C	Sep 12	1326	TT	D-1-e		241	185	51.5	88.7	Sep 15	Sep 15(3)	Launched Luna 16.
Luna 16	72A					4,820? to Moon 1,880 landed	106	15	71	114	Sep 24(12)	unknown	Landed on Moon Sep 20, lift off Sep 21. Recovered on Earth.

Kosmos 362	73A	Sep 16	1200	PL	B-1		854	281	71	95.7	Oct 13(392)	Mar 28(192)	Military.
Kosmos 363	74A	Sep 17	0824	TT	A-2		324	210	65	89.6	Sep 29(12)	Sep 22(5)	Observation. Probably recovered.
Kosmos 364	75A	Sep 22	1258	PL	A-2		330	211	65.4	89.6	Oct 2(12)	Sep 28(6)	Observation. Probably recovered. Separated a module.
Kosmos 365	76A	Sep 25	1410	TT	F-1-r		210	144	49.5		Sep 25(0)	Sep 26(1)	FOBS test.
Tyazheliy Sputnik	77C	Sep 29	0824	PL	A-2-e		469	228	65.4	91.5	Oct 23(24)	Oct 16(17)	Launched Molniya 1-15.
Molniya 1-15	77A						39,300	480	65.5	706		Jun 2(612)	Communications satellite.
Kosmos 366	78A	Oct 1	0824	TT	A-2		310	206	65	89.5	Oct 13(12)	Oct 6(5)	Observation. Probably recovered.
Kosmos 367	79A	Oct 3	1034	TT	F-1-m	first later	264 1,030	246 932	65.1 65.3	89.6 104.5		Oct 6(3)	Maneuverable. Ocean surveillance.
Kosmos 368	80A	Oct 8	1243	TT	A-2		421	212	65	90.6	Oct 14(6)	Oct 20(12)	Observation. Probably recovered. Separated a capsule.
													Biology experiment.
Kosmos 369	81A	Oct 8	1507	PL	B-1		534	278	71	92.3	Jan 22(106)	Nov 30(53)	Military.
Kosmos 370	82A	Oct 9	1102	TT	A-2		307	208	65	89.5	Oct 22(13)	Oct 13(4)	Observation. Probably recovered. Separated a module.
Kosmos 371	83A	Oct 12	1955	PL	C-1		780	754	74	99.9			Possible navigation satellite.
Inter-kosmos 4	84A	Oct 14	1131	KY	B-1		668	263	48.5	93.6	Jan 7(85)	Dec 17(64)	Soviet bloc science. Solar radiation.
Meteor 6	85A	Oct 15	1131	PL	A-1		674	633	81.2	97.5			Weather satellite.
Kosmos 372	86A	Oct 16	1507	PL	C-1		828	786	74	100.8			Possible communications satellite.
Kosmos 373	87A	Oct 20	0546	TT	F-1-m	first later	1,102 553	510 490	62.8 62.9	100.9 94.8		Jan 18(90)	Maneuverable target for intercept.
Tyazheliy Sputnik	88C	Oct 20	1955	TT	D-1-e		223	202	51.5	88.7	Oct 26(6)	Oct 26(6)	Launched Zond 8.
Zond 8	88A										Oct 27(7)		Circumlunar vehicle. Recovered.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Kosmos 374	89A	Oct 23	0419	TT	F-1-m	first later	1,053 2,153	530 536	62.9 63	100.6 112.3			Maneuverable interceptor. Near pass on 373. Exploded.
Kosmos 375	91A	Oct 30	0210	TT	F-1-m	first later	1,000 2,164	500 538	629 63	100.6 112.4			Maneuverable interceptor. Near pass on 373. Exploded.
Kosmos 376	92A	Oct 30	1326	PL	A-2		311	216	65.4	89.5	Nov 12(13)	Nov 5(6)	Observation. Probably recovered. Separated a module.
Tyazheliy Sputnik	95C	Nov 10	1438	TT	D-1-e		237	192	51.6	88.7	Nov 13(3)	Nov 13(3)	Launched Luna 17
Luna 17	95A					4,820	Moon 85	19	141	114	Nov 17(7)	unknown	Soft landed Lunokhod-1 to rove on Moon, 756 kg.
Kosmos 377	96A	Nov 11	0922	TT	A-2		305	208	65	89.4	Nov 23(12)	Nov 16(5)	Observation. Probably recovered.
Kosmos 378	97A	Nov 17	1829	PL	C-1		1,763	241	74	105	Aug 17(639)	Sep 30(683)	Ionospheric studies.
Kosmos 379	99A	Nov 24	0517	TT	A-2-m	first later	253 14,035	193 175	51.6 51.7	88.7 250.6		Nov 26(2)	Possible manned precursor.
Kosmos 380	100A	Nov 24	1102	PL	B-1		1,548	210	82	102.2	Jun 17(205)	Apr 9(136)	Military.
Tyazheliy Sputnik	101C	Nov 27	1550	PL	A-2-e		434	216	65.4	91.0	Dec 17(20)	Dec 11(14)	Launched Molniya 1-16
Molniya 1-16	101A						39,430	435	65.3	707			Communications satellite.
Kosmos 381	102A	Dec 2	0405	PL	C-1		1,023	985	74	105			Top side ionospheric sounder.
Kosmos 382	103A	Dec 2	1634	TT	D-1-m	first later	5,040 5,082	320 2,577	51.6 55.9	143 171.1			Possible manned precursor.
Kosmos 383	104A	Dec 3	1355	PL	A-2		293	208	65.4	89.3	Dec 16(13)	Dec 9(6)	Observation. Probably recovered. Maneuvered but no separated module.
Kosmos 384	105A	Dec 10	1117	PL	A-2		314	212	72.9	89.5	Dec 22(12)	Dec 15(5)	Observation. Probably recovered. Separated a capsule.
Kosmos 385	108A	Dec 12	1258	PL	C-1		1,005	982	74	104.8			Possible navigation satellite.

Kosmos 386	110A	Dec 15	1005	TT	A-2		275	207	65	89.2	Dec 28(13)	Dec 19(4)	Observation. Probably recovered. Separated a module.
Kosmos 387	111A	Dec 16	0434	PL	C-1		560	528	74	95.3			Possible ferret satellite.
Kosmos 388	112A	Dec 18	0936	PL	B-1		532	281	71	92.3	May 10(143)	Feb 17(61)	Military.
Kosmos 389	113A	Dec 18	1619	PL	A-1		699	655	81	98.1			Possible ferret.
Tyazheliy Sputnik	114C	Dec 25	0350	TT	A-2-e		472	240	65.0	91.7	Feb 10(47)	Jan 23(29)	Launched Molniya 1-17.
Molniya 1-17	114A						39,600	480	65	712			Communications satellite.
	1971	1971											
Kosmos 390	1A	Jan 12	0936	TT	A-2		296	208	65	89.3	Jan 25(13)	Jan 17(5)	Observation. Probably recovered. Separated a module.
Kosmos 391	2A	Jan 14	1200	PL	B-1		822	277	71	95.4	Feb 21(403)	Aug 21(219)	Military.
Meteor 7	3A	Jan 20	1131	PL	A-1		679	630	81.2	97.6			Weather satellite.
Kosmos 392	4A	Jan 21	0838	TT	A-2		300	207	65	89.4	Feb 2(12)	Jan 26(5)	Observation. Probably recovered.
Kosmos 393	7A	Jan 26	1243	PL	B-1		512	283	71	92.2	Jun 16(141)	Mar 31(64)	Military.
Kosmos 394	10A	Feb 9	1858	PL	C-1		619	574	65.9	96.5			Target for intercept.
Kosmos 395	13A	Feb 18	2107	PL	C-1		570	534	74	95.4			Possible ferret satellite.
Kosmos 396	14A	Feb 18	1410	PL	A-2		310	211	65.4	89.4	Mar 3(13)	Feb 25(7)	Observation. Probably recovered. Separated a module.
Kosmos 397	15A	Feb 25	1117	TT	F-1-m	first later	613 2,317	144 593	65.1 65.8	92.1 114.7		Mar 4(7)	Maneuverable interceptor. Near pass on 394. Exploded.
Kosmos 398	16A	Feb 26	0517	TT	A-2-m	first later	276 10,903	196 203	51.6 51.6	88.9 216.1		Mar 1(3)	Possible manned precursor.
Kosmos 399	17A	Mar 3	0936	TT	A-2		310	209	65	89.5	Mar 17(14)	Mar 8(5)	Observation. Probably recovered. Separated a module.
Kosmos 400	20A	Mar 19	2150	PL	C-1		1,016	995	65.8	105			Target for intercept.
Kosmos 401	23A	Mar 27	1102	PL	A-2		322	216	72.9	89.6	Apr 9(13)	Apr 2(6)	Observation. Probably recovered. Separated a module.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Kosmos 402	25A	Apr 1	1131	TT	F-1-m	first later	279 1,036	261 948	65 65.0	89.7 104.9		May 6(36)	Maneuverable. Ocean surveillance.
Kosmos 403	26A	Apr 2	0824	PL	A-2		251	216	81.4	89	Apr 14(12)	Apr 5(3)	Observation. Probably recovered.
Kosmos 404	27A	Apr 4	1424	TT	F-1-m	first second later	632 1,009 740	148 811 136	65.1 65.9 65.1	92.3 103 93.3	Apr 4(0)	Apr 12(8)	Maneuverable interceptor. Near pass on 400. Steered to decay over ocean.
Kosmos 405	28A	Apr 7	0712	PL	A-1		706	676	91.3	98.3			Possible ferret.
Kosmos 406	29A	Apr 14	0810	PL	A-2		264	223	81.3	89.2	Apr 24(10)	Apr 17(3)	Observation. Probably recovered. Separated a module.
Meteor 8	31A	Apr 17	1146	PL	A-1		646	620	81.2	97.2			Weather satellite.
Salyut 1	32A	Apr 19	0140	TT	D-1	18,600?	first 222 later 269	200 249	51.6 51.6	88.5 89.6	Oct 11(175)	Apr 20(1)	Launched as unmanned for later manning.
Soyuz 10	34A	Apr 22	2354	TT	A-2	6,565?	246	208	51.6	90	Apr 24(2)	Apr 25(3)	Shatalov, Yeliseyev, Rukavishnikov. Docked with Salyut 1. Recovered.
Kosmos 407	35A	Apr 23	1131	PL	C-1		844	799	74	101			Possible communications satellite.
Kosmos 408	37A	Apr 24	1117	PL	B-1		1,542	211	82	107.1	Dec 29(249)	Sep 29(158)	Military.
Kosmos 409	38A	Apr 28	1438	PL	C-1		1,222	1,185	74	109.4			Possible navigation/geodetic satellite.
Kosmos 410	40A	May 6	0629	TT	A-2		300	207	65	89.4	May 18(12)	May 11(5)	Observation. Probably recovered. Separated a capsule.
Kosmos 411	41A	May 7	1424	PL	C-1		1,530	1,408	74.5	115			Octuple launch. Possible communications satellites.
Kosmos 412	41B						1,530	1,408	74.5	115			
Kosmos 413	41C						1,530	1,408	74.5	115			
Kosmos 414	41D						1,530	1,408	74.5	115			
Kosmos 415	41E						1,530	1,408	74.5	115			
Kosmos 416	41F						1,530	1,408	74.5	115			
Kosmos 417	41G						1,530	1,408	74.5	115			
Kosmos 418	41H						1,530	1,408	74.5	115			
Kosmos 419	42A	May 10	1702	TT	D-1-e	4,650	174	159	51.4	87.7	May 12(2)	attached	Mars failure. Earth orbit only.
Mars	42A												

Kosmos 420	43A	May 18	0810	TT	A-2		242	200	51.8	88.8	May 29(11)	May 21(3)	Observation. Probably recovered. Separated a module.
Kosmos 421	44A	May 19	1019	PL	B-1		492	283	71	92	Nov 8(173)	Aug 23(96)	Military.
Tyazheliy Sputnik	45C	May 19	1619	TT	D-1-e		173	137	51.5	87.5	May 21(2)	May 21(2)	Launched Mars 2.
Mars 2	45A					4,650	25,000	1,380	48.9	1,080.0	Mars orbit	solar orbit	
Lander	45D										Nov 27(189)		Struck Mars.
Kosmos 422	46A	May 22	0043	PL	C-1		1,020	994	74	105.1			Possible navigation satellite.
Kosmos 423	47A	May 27	1200	PL	B-1		511	282	71	92.2	Nov 26(183)	Aug 29(94)	Military.
Kosmos 424	48A	May 28	1034	PL	A-2		309	214	65.4	89.4	Jun 10(13)	Jun 3(6)	Observation. Probably recovered. Separated a module.
Tyazheliy Sputnik	49C	May 28	1522	TT	D-1-e		234	140	51.6	88.2	May 31(3)	May 31(3)	Launched Mars 3.
Mars 3	49A					4,650	190,700	1,500	48.9?	15,840	Mars orbit	solar orbit	
Lander	49F										Dec 2(188)		Soft landed on Mars.
Kosmos 425	50A	May 29	0350	PL	C-1		556	511	74	95.3			Possible ferret satellite.
Kosmos 426	52A	Jun 4	1814	PL	C-1		2,012	394	74	109.3			Probable ionospheric studies.
Soyuz 11	53A	Jun 6	0455	TT	A-2	6,565?	217	185	51.6	88.3	Jun 29(23)	Jun 7(1)	Dobrovolskiy, Volkov, Patseyev. Docked with Salyut 1. Died during Earth return.
Kosmos 427	55A	Jun 11	1005	PL	A-2		337	211	72.9	89.7	Jun 23(12)	Jun 20(9)	Observation. Probably recovered. Separated a module.
Kosmos 428	57A	Jun 24	0810	TT	A-2		271	208	51.8	89.1	Jul 6(13)	Jun 28(4)	Observation. Probably recovered. Separated a capsule. Electron and gamma flux studies.
Meteor 9	59A	Jul 16	0126	PL	A-1		650	618	81.2	97.3			Weather satellite.
Kosmos 429	61A	Jul 20	1005	TT	A-2		260	204	51.8	89	Aug 2(13)	Jul 23(3)	Observation. Probably recovered. Separated a module.
Kosmos 430	62A	Jul 23	1102	PL	A-2		322	206	65.4	89.6	Aug 5(13)	Jul 29(6)	Observation. Probably recovered. Separated a module.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Tyazheliy Sputnik	64B	Jul 28	0336	PL	A-2-e		459	217	65.4	91.3	Sep 29(63)	Sep 24(59)	Launched Molniya 1-18.
Molniya 1-18	64A						39,300	470	65.4	705			Communications satellite.
Kosmos 431	65A	Jul 30	0838	TT	A-2		262	202	51.8	89	Aug 11(12)	Aug 4(5)	Observation. Probably recovered.
Kosmos 432	66A	Aug 5	1005	TT	A-2		262	209	51.8	89	Aug 18(13)	Aug 9(4)	Observation. Probably recovered. Separated a module.
Kosmos 433	68A	Aug 8	2346	TT	F-1-r		259	159	49.5	88.5	Aug 9(1)	Aug 10(2)	FOBS.
Kosmos 434	69A	Aug 12	0535	TT	A-2-m	first later	285 11,804	197 186	51.6 51.6	89 228.2		Aug 18(6)	Manned precursor.
Kosmos 435	72A	Aug 27	1102	PL	B-1		505	282	71	92.1	Jan 28(154)	Nov 20(85)	Military.
Tyazheliy Sputnik	73C	Sep 2	1341	TT	D-1-e	242	186	51.6	88.7	Sep 7(5)		Sep 7(5)	Launched Luna 18.
Luna 18	73A					1,880?	100	18	35	114	Sep 11(9)	Solar orbit	Lunar orbit September 7, 1971. Signals ceased at touchdown on Moon.
Kosmos 436	74A	Sep 7	0126	PL	C-1		550	514	74	95.2			Possible ferret satellite.
Kosmos 437	75A	Sep 10	0350	PL	C-1		558	523	74	95.3			Possible ferret satellite.
Kosmos 438	77A	Sep 14	1258	PL	A-2		321	212	65.4	89.5	Sep 27(13)	Sep 22(8)	Observation. Probably recovered. Separated a module.
Kosmos 439	78A	Sep 21	1200	PL	A-2		308	219	65.4	89.4	Oct 2(11)	Sep 27(6)	Observation. Probably recovered.
Kosmos 440	79A	Sep 24	1034	PL	B-1		814	282	71	95.3	Oct 29(400)	May 19(228)	Military.
Kosmos 441	81A	Sep 28	0741	TT	A-2		228	209	65	89.2	Oct 19(12)	Oct 3(5)	Observation. Probably recovered. Separated a module.
Tyzaheliy Sputnik	82B	Sep 28	1000	TT	D-1-e		260	172	51.6	88.8	Oct 1(3)	Oct 1(3)	Launched Luna 19.
Luna 19	82A					4,820?	first 140 later 385	140 77	40.6 40.7	121.8 131	lunar orbit	unknown	Lunar survey from orbit. Returned facsimile pictures.
Kosmos 442	84A	Sep 29	1131	PL	A-2		321	211	72.9	89.5	Oct 12(13)	Oct 6(7)	Observation. Probably Recovered. Separated a module.

Kosmos 443	85A	Oct 7	1220	PL	A-2	325	211	65.4	89.6	Oct 19(12)	Oct 13(6)	Observation. Probably recovered. Separated a capsule.
Kosmos 444	86A	Oct 13	1341	PL	C-1	1,550	1.415	74	115			Octuple launch. Possible communications satellites.
Kosmos 445	86B					1,550	1,415	74	115			
Kosmos 446	86C					1,550	1,415	74	115			
Kosmos 447	86D					1,550	1,415	74	115			
Kosmos 448	86E					1,550	1,415	74	115			
Kosmos 449	86F					1,550	1,415	74	115			
Kosmos 450	86G					1,550	1,415	74	115			
Kosmos 451	86H					1,550	1,415	74	115			
Kosmos 452	88A	Oct 14	0907	TT	A-2	270	201	65	89.1	Oct 27(13)	Oct 18(4)	Observation. Probably recovered. Separated a module.
Kosmos 453	90A	Oct 19	1243	PL	B-1	522	281	71	92.2	Mar 19(152)	Jan 1(74)	Military.
Kosmos 454	94A	Nov 2	1424	PL	A-2	284	210	66.4	89.2	Nov 16(14)	Nov 6(4)	Observation. Probably recovered. Separated a module.
Kosmos 455	97A	Nov 17	1117	PL	B-1	516	282	71	92.2	Apr 9(144)	Feb 8(83)	Military.
Kosmos 456	98A	Nov 19	1200	PL	A-2	328	218	72.9	89.7	Dec 2(13)	Nov 25(6)	Observation. Probably recovered. Separated a module.
Kosmos 457	99A	Nov 20	1800	PL	C-1	1,229	1,192	74	109.5			Possible navigation/geodetic satellite.
Tyazheliy Sputnik	100C	Nov 24	0936	PL	A-2-e	465	225	65.4	91.4	Dec 30(36)	Dec 19(25)	Launched Molniya 2-1.
Molniya 2-1	100A					39,350	460	65.4	706.0			Communications satelite.
Kosmos 458	101A	Nov 29	1019	PL	B-1	523	281	71	92.3	Apr 20(143)	Feb 14(77)	Military.
Kosmos 459	102A	Nov 29	1731	PL	C-1	277	226	65.8	89.4	Dec 27(28)	Dec 11(12)	Target for intercept.
Kosmos 460	103A	Nov 30	1648	PL	C-1	553	520	74	95.2			Possible ferret satellite.
Interkosmos 5	104A	Dec 2	0824	KY	B-1	1,200	205	48.4	98.5	Apr 7(127)	Mar 2(91)	Science for Soviet bloc. Cosmic rays, fluxes of charged particles.
Kosmos 461	105A	Dec 2	1731	PL	C-1	524	490	69.2	94.6			Gamma radiation studies.
Kosmos 462	106A	Dec 3	1312	TT	F-1-m	first 1,561 later 1,840	143 237	62.3 65.8	102.0 105.7		Jan 3(31)	Maneuverable interceptor. Near pass on Kosmos 459. Exploded.
Kosmos 463	107A	Dec 6	0950	TT	A-2	307	215	65.0	89.4	Dec 11(5)	Dec 11(5)	Observation. Probably recovered. Separated a module.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Kosmos 464	108A	Dec 10	1102	PL	A-2		405	206	72.9	90.3	Dec.16(6)	Dec 24(14)	Observation. Probably recovered. Separated a module.
Kosmos 465	111A	Dec 15	0434	PL	C-1		1,023	984	74	105			Possible navigation satellite.
Kosmos 466	112A	Dec 16	0950	TT	A-2		302	207	65	89.4	Dec 27(11)	Dec 21(5)	Observation. Probably recovered. Separated a module.
Kosmos 467	113A	Dec 17	1048	PL	B-1		502	279	71	91	Apr 18(123)	Feb 17(62)	Military.
Kosmos 468	114A	Dec 17	1258	PL	C-1		830	788	74	100.8			Possible communications satellite.
Tyazheliy Sputnik	115D	Dec 20	2302	PL	A-2-e		489	222	65.4	91.6	Jan 27(38)	Jan 26(37)	Launched Molniya 1-19.
Molniya 1-19	115A						39,200	490	65.5	703			Communications satellite.
Kosmos 469	117A	Dec 25	1131	TT	F-1-m	first later	276 1,023	259 941	65 64.5	89.7 104.7		Feb 9(46)	Maneuverable. Ocean surveillance.
Kosmos 470	118A	Dec 27	1410	PL	A-2		272	195	65.4	89.1	Jan 6(10)	Dec 30(3)	Observation. Probably recovered. Separated a module.
Oreol 1	119A	Dec 27	1858	PL	C-1		2,500	410	74	114.6			Scientific satellite for French auroral studies.
Meteor 10	120A	Dec 30	1048	PL	A-1		905	880	81.2	102.7			Weather satellite.
Kosmos 471	1972 1A	1972 Jan 12	1005	TT	A-2		323	202	65	89.5	Jan 25(13)	Jan 20(8)	Observation. Probably recovered. Separated a module.
Kosmos 472	4A	Jan 25	1117	PL	B-1		1,568	207	82	102.4	Aug 18(206)	May 6(102)	Military.
Kosmos 473	6A	Feb 3	0840	TT	A-2		333	209	65	89.7	Feb 15(12)	Feb 11(8)	Observation. Probably recovered.
Tyazheliy Sputnik	7C	Feb 14	0328	TT	D-1-e		238	191	51.5	88.7	Feb 17(3)	Feb 17(3)	Launched Luna 20.
Luna 20	7A					1,880?	100	21	65	144	Feb 25(11)	unknown	Landed on Moon Feb 21. Liftoff Feb 22. Recovered on Earth.

Kosmos 474	8A	Feb 16		TT	A-2		347	207	65	89.9	Feb 29(13)		Observation. Probably recovered. Separated a module.
Kosmos 475	9A	Feb 25		TT	C-1		1,013	977	74	105			Possible navigation satellite.
Kosmos 476	11A	Mar 1		PL	A-1		651	618	81.2	97.2			Possible ferret.
Kosmos 477	13A	Mar 4		PL	A-2		329	212	72.9	89.6			Observation. Probably recovered. Separated a module. Particle fluxes, radiation.
Kosmos 478	15A	Mar 15	1200	PL	A-2		319	213	65.4	89.5	Mar 28(13)	Mar 21(6)	Observation. Recovered. Separated a module.
Kosmos 479	17A	Mar 22	2031	PL	C-1		549	517	74	95.2			Possible ferret.
Kosmos 480	19A	Mar 25	0200	PL	C-1		1,212	1,183	83	109.2			Possible navigation / geodetic satellite.
Kosmos 481	20A	Mar 25	1040	PL	B-1		540	270	71	92.4	Sep 2(161)	Jun 11(78)	Geomagnetic studies.
Tyazheliy Sputnik	21C	Mar 27	0415	TT	A-2-e		241	194	51.8	88.6	Mar 29(2)	Mar 29(2)	Launched Venera 8.
Venera 8	21A					1,180	1.08 au	.72 au	0.2	313D	Jul 22(117)	solar orbit	Returned data from surface of Venus.
Meteor 11	22A	Mar 30	1405	PL	A-1		903	878	81.2	102.6			Weather satellite.
Tyazheliy Sputnik	23C	Mar 31	0403	TT	A-2-e		237	179	51.7	88.6	Apr 2(2)	Apr 1(1)	Launched Kosmos 482.
Kosmos 482 (Venera)	23A					1,180?	9,813	210	52	201.4			Venera failed to leave Earth orbit.
Kosmos 483	24A	Apr 3	1015	PL	A-2		345	212	72.9	89.9	Apr 15(12)	Apr 11(11)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	25D	Apr 4	2039	PL	A-2-e		473	231	65.5	91.6	May 8(34)	Apr 28(24)	Launched Molniya 1-20.
Molniya 1-20	25A						39,260	480	65.6	695	Jan 30(666)	Mar 8(703)	Communications satellite.
MAS-1	25B					15	39,250	458	65.6	704.7			French engineering test.
Kosmos 484	26A	Apr 5	0800	PL	A-2		236	203	81.3	88.8	Apr 18(13)	Apr 8(3)	Observation. Recovered. Separated a module. Cosmic ray studies.
Interkosmos 6	27A	Apr 7	1000	TT	A-2		256	203	51.8	89	Apr 11(4)	Apr 10(3)	High energy cosmic rays. Recovered.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Kosmos 485	28A	Apr 11	1105	PL	B-1		506	280	71	92.1	Aug 30(141)	Jun 16(66)	Military.
Tyazheliy Sputnik	29C	Apr 14	0055	TT	A-2-e		459	228	65.0	91.4	May 17(33)	May 11(27)	Launched Prognoz 1.
Prognoz 1	29A					845	200,000	950	65	5,320			Solar radiation studies.
Kosmos 486	30A	Apr 14	0801	PL	A-2		267	214	81.4	89.1	Apr 27(13)	Apr 17(3)	Observation. Recovered. Separated a module.
Kosmos 487	33A	Apr 21	1201	PL	B-1		531	278	71	92.3	Sep 24(156)	Jul 3(73)	Military.
Kosmos 488	34A	May 5	1120	PL	A-2		319	211	65.4	89.5	May 18(13)	May 11(6)	Observation. Recovered. Separated a module.
Kosmos 489	35A	May 6	1125	PL	C-1		1,010	980	74	105			Possible navigation satellite.
Kosmos 490	36A	May 17	1020	PL	A-2		310	212	65.4	89.4	May 29(12)	May 23(6)	Observation. Recovered. Separated a module. High energy electron flux and cosmic rays.
Tyazheliy Sputnik	37C	May 19	1438	PL	A-2-e		463	207	65.4	91.2	Jun 9(21)	Jun 8(20)	Launched Molniya 2-2.
Molniya 2-2	37A						39,300	460	65.5	705			Communications satellite.
Kosmos 491	38A	May 25	0635	TT	A-2		303	210	65	89.5	Jun 9(14)	May 30(5)	Observation. Recovered. Separated a module.
Kosmos 492	40A	Jun 9	0700	TT	A-2		342	209	65	89.8	Jun 22(13)	Jun 18(9)	Observation. Recovered. Separated a module.
Kosmos 493	42A	Jun 21	0625	TT	A-2		308	313	65	89.5	Jul 3 (12)	Jun 25(4)	Observation. Recovered.
Kosmos 494	43A	Jun 23	0924	PL	C-1		829	791	74	100.8			Possible communications satellite.
Kosmos 495	44A	Jun 23	1120	PL	A-2		298	206	65.4	89.3	Jul 6(13)	Jun 29(6)	Observation. Recovered. Separated a module.
Kosmos 496	45A	Jun 26	1453	TT	A-2	6570?	342	195	51.6	89.6	Jul 2(6)	Jul 2(6)	Manned precursor.
Tyazheliy Sputnik	46C	Jun 29	0347	TT	A-2-e		469	235	64.9	91.6	Aug 13(45)	Aug 1(33)	Launched Prognoz 2.
Prognoz 2	46A					845	200,000	550	65	5820			Solar radiation studies.
Interkosmos 7	47A	Jun 30	0558	KY	B-1		568	267	48.4	92.6	Oct 5(97)	Sep 29(91)	Solar UV and X-ray studies.
Kosmos 497	48A	Jun 30	0920	PL	B-1		812	282	71	95.2	Nov 7(495)	Mar 17(260)	Military.

Meteor 12	49A	Jun 30	1912	PL	A-1	929	897	81.2	103			Weather satellite.
Kosmos 498	50A	Jul 5	0930	PL	B-1	511	282	71	92.1	Nov 25(143)	Sep 27(84)	Military.
Kosmos 499	51A	Jul 6	1040	TT	A-2	283	209	51.8	89.2	Jul 17(9)	Jul 10(4)	Observation. Recovered. Separated a module.
Kosmos 500	53A	Jul 10	1615	PL	C-1	554	509	74	95.2			Possible ferret.
Kosmos 501	54A	Jul 12	0600	KY	B-1	2,149	222	48.5	108.8	Mar 9(666)	Jun 10(333)	Military.
Kosmos 502	55A	Jul 13	1430	PL	A-2	284	206	65.4	89.2	Jul 25(12)	Jul 18(5)	Observation. Recovered. Separated a module.
Kosmos 503	56A	Jul 19	1345	PL	A-2	304	208	65.4	89.4	Aug 1(13)	Jul 27(8)	Observation. Recovered. Separated a module.
Kosmos 504 Kosmos 505 Kosmos 506 Kosmos 507 Kosmos 508 Kosmos 509 Kosmos 510 Kosmos 511	57A 57B 57C 57D 57E 57F 57G 57H	Jul 20	1811	PL	C-1	1,540	1,425	74	115.2			Octuple launch. Possible communications satellites.
Kosmos 512	59A	Jul 28	1020	PL	A-2	294	207	65.4	89.3	Aug 9(12)	Aug 1(4)	Observation. Recovered.
Kosmos 513	60A	Aug 2	0815	TT	A-2	340	209	65	89.8	Aug 15(13)	Aug 9(7)	Observation. Recovered. Separated a module.
Kosmos 514	62A	Aug 16	1340	PL	C-1	999	959	83	104.4			Possible navigation satellite.
Kosmos 515	63A	Aug 18	1000	PL	A-2	300	203	72.9	89.3	Aug 31(13)	Aug 23(5)	Observation. Recovered. Separated a module.
Kosmos 516	66A	Aug 21	1030	TT	F-1-m	first 277 later 1,030	256 920	65 64.8	89.6 104.6		Sep 25(35)	Ocean surveillance.
Kosmos 517	67A	Aug 30	0820	TT	A-2	305	207	65	89.4	Sep 11(12)	Sep 3(4)	Observation. Recovered.
Kosmos 518	70A	Sep 15	0940	PL	A-2	330	208	72.9	89.6	Sep 24(9)	Sep 22(7)	Observation. Recovered. Separated a module.
Kosmos 519	71A	Sep 16	0820	TT	A-2	343	210	71.3	89.8	Sep 26(10)	Sep 24(8)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	72C	Sep 19	1920	PL	A-2-e	607	214	62.8	92.8	Nov 5(47)	Oct 20(31)	Launched Kosmos 520.
Kosmos 520	72A					39,319	652	62.8	710			Possible early warning satellite.
Kosmos 521	74A	Sep 29	2018	PL	C-1	1,030	973	65.8	105			Possible target for intercept.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Tyazheliy Sputnik	75C	Sep 30	2020	PL	A-2-e		466	230	65.4	91.5			Launched Molniya 2-3.
Molniya 2-3	75A						39,200	480	65.3	703			Communications satellite.
Kosmos 522	77A	Oct 4	1200	PL	A-2		342	214	72.9	89.8	Oct 17(13)	Oct 14(10)	Observation. Recovered. Separated a module.
Kosmos 523	78A	Oct 5	1130	PL	B-1		507	283	71	92	Mar 7(153)	Dec 7(76)	Military.
Kosmos 524	80A	Oct 11	1320	PL	B-1		537	277	71	92.3	Mar 25(164)	Dec 20(70)	Military.
Tyazheliy Sputnik	81C	Oct 14	0615	PL	A-2-e		488	223	65.4	91.7	Nov 16(33)	Nov 4(21)	Launched Molniya 1-21.
Molniya 1-21	81A						39,300	480	65.3	705		Mar 16(883)	Communications satellite.
Kosmos 525	83A	Oct 18	1200	PL	A-2		292	208	65.4	89.3	Oct 29(11)	Oct 22(4)	Observation. Recovered. Separated a module.
Kosmos 526	84A	Oct 25	1048	PL	B-1		511	282	71	92	Apr 8(165)	Jan 8(75)	Military.
Meteor 13	85A	Oct 26	1614	PL	A-1		904	893	81.2	102.6			Weather satellite.
Kosmos 527	86A	Oct 31	1341	PL	A-2		330	214	65.4	89.7	Nov 13(13)	Nov 8(8)	Observation. Recovered. Separated a module.
Kosmos 528 Kosmos 529 Kosmos 530 Kosmos 531 Kosmos 532 Kosmos 533 Kosmos 534 Kosmos 535	87A 87B 87C 87D 87E 87F 87G 87H	Nov 1	0155	PL	C-1		1,495	1,375	74	114			Octuple launch. Possible communications satellites.
Kosmos 536	88A	Nov 3	0141	PL	C-1		555	514	74	95.2			Possible ferret.
Kosmos 537	93A	Nov 25	0910	TT	A-2		324	207	65	89.6	Dec 7(12)	Dec 2(7)	Observation. Recovered.
Interkosmos 8	94A	Nov 30	2150	PL	B-1		670	214	71	93.2	Mar 2(92)	Jan 12(43)	Ionospheric electrons and temperature.
Tyazheliy Sputnik	95C	Dec 2	0440	TT	A-2-e		531	210	65.0	91.3	Feb 1(61)	Jan 10(39)	Launched Molniya 1-22.
Molniya 1-22	95A						39,100	500	65	703		Feb 25 (815)	Communications satellite.
Tyazheliy Sputnik	98C	Dec 12	0651	PL	A-2-e		467	220	65.4	91.4	Jan 19 (38)	Jan 13(32)	Launched Molniya 2-4.
Molniya 2-4	98A						39,300	470	65.3	705	Jan 22(771)	Oct 7(664)	Communications satellite.

Kosmos 538	99A	Dec 14	1339	PL	A-2		305	212	65.4	89.4	Dec 27(13)	Dec 22(8)	Observation. Recovered. **Separated a module.**
Kosmos 539	102A	Dec 21	0155	PL	C-1		1,353	1,302	74	113			Possible navigation/geodetic satellite.
Kosmos 540	104A	Dec 25	2305	PL	C-1		823	779	74	100.8			Possible communications satellite.
Kosmos 541	105A	Dec 27	1030	PL	A-2		371	242	81.4	90.3	Jan 8(12)	Jan 12(12)	Observation. Recovered. Separated a module.
Kosmos 542	106A	Dec 28	1100	PL	A-1		653	554	81.2	96.4			Possible ferret.
Tyazheliy Sputnik	1973 1C	1973 Jan 8	0655	TT	D-1-e		236	183	51.6	88.6	Jan 13(5)	Jan 12(4)	Launched Luna 21.
Luna 21	1A						110	90	60	118	Jan 15(7)	unknown	Landed Lunokhod 2 after entering lunar orbit Jan. 12.
Kosmos 543	2A	Jan 11	2136	TT	A-2		333	211	65	89.7	Jan 24(13)	Jan 22(11)	Observation. Recovered. Separated a module.
Kosmos 544	3A	Jan 20	0336	PL	C-1		561	513	74	95.3			Ferret.
Kosmos 545	4A	Jan 24	1145	PL	B-1		521	279	71	92.2	Jul 31(188)	Apr 21(87)	Military.
Kosmos 546	5A	Jan 26	1146	KY	C-1		630	585	50.7	96.6			Possible solar studies.
Kosmos 547	6A	Feb 1	0830	TT	A-2		330	208	65	89.7	Feb 13(12)	Feb 9(8)	Observation. Recovered.
Tyazheliy Sputnik	7C	Feb 3	0548	TT	A-2-e		472	228	65.0	91.5	Mar 18(43)	Mar 13(38)	Launched Molniya 1-23.
Molniya 1-23	7A						39,200	470	65	703			Communications satellite.
Kosmos 548	8A	Feb 8	1315	PL	A-2		322	214	65.4	89.6	Feb 21(13)	Feb 16(8)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	9C	Feb 15	0012	TT	A-2-e		484	216	65.0	91.5	Mar 23(36)	Mar 22(35)	Launched Prognoz 3.
Prognoz 3	9A					845	200,000	590	65	5783			Solar radiation studies.
Kosmos 549	10A	Feb 28	0437	PL	C-1		556	513	74	95.2			Ferret.
Kosmos 550	11A	Mar 1	1240	PL	A-2		325	217	65.4	89.6	Mar 11(10)	Mar 9(8)	Observation. Recovered. Separated a module.
Kosmos 551	12A	Mar 6	0920	TT	A-2		316	210	65	89.5	Mar 20(14)	Mar 13(7)	Observation. Recovered. Separated a module.
Meteor 14	15A	Mar 20	1120	PL	A-3		903	882	81.2	1026			Weather satellite.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Kosmos 552	16A	Mar 22	1000	PL	A-2		337	211	72.9	89.7	Apr 3(12)	Mar 30(8)	Observation. Recovered. Separated a module.
Salyut 2	17A	Apr 3	0900	TT	D-1	18,900?	278	257	51.6	89.8	May 28(55)	Apr 6(3)	Intended to be a manned station. Malfunctioned.
Tyazheliy Sputnik	18C	Apr 5	1113	PL	A-2-e		456	217	65.4	91.3	Apr 30(25)	Apr 24(19)	Launched Molniya 2-5
Molniya 2-5	18A						39,100	500	65	702			Communications satellite.
Kosmos 553	20A	Apr 12	1200	PL	B-1		519	282	71	92.2	Nov 11(213)	Aug 7(117)	Military.
Kosmos 554	21A	Apr 19	0900	PL	A-2		318	212	72.9	89.5	May 27(38)	Apr 26(7)	Observation. Recovery failed so exploded. Separated a module.
Interkosmos Kopernik 500	22A	Apr 19	1020	KY	B-3		1,551	202	48.5	102.2	Oct 19(179)	Oct 17(177)	Solar radiation and iono-spheric radiowave excitation.
Kosmos 555	24A	Apr 25	2136	PL	A-2		253	216	81.3	89	May 7(12)	Apr 28(3)	Observation. Recovered. Separated a module.
Kosmos 556	25A	May 5	0700	PL	A-2		252	209	81.3	89	May 14(9)	May 8(3)	Observation. Recovered. Separated a module.
Kosmos 557	26A	May 11	0120	TT	D-1	18,900?	226	218	51.6	89.1	May 22(11)	May 17(6)	Intended to be a Salyut manned station. Early failure.
Kosmos 558	29A	May 17	1326	PL	B-3		526	279	71	92.3	Dec 22(219)	Sep 10(116)	Military.
Kosmos 559	30A	May 18	1102	PL	A-2		345	217	65.4	89.8	May 23(5)	May 28(10)	Observation. Recovered. Separated a module.
Kosmos 560	31A	May 23	1030	PL	A-2		336	211	72.9	89.7	Jun 5(13)	Jun 1(9)	Observation. Recovered. Separated a module.
Kosmos 561	33A	May 25	1330	PL	A-2		317	215	65.4	89.5	Jun 6(12)	Jun 2(8)	Observation. Recovered. Seperated a module. Gamma ray telescope.
Meteor 15	34A	May 29	1017	PL	A-1		909	867	81.2	102.5			Weather satellite.
Kosmos 562	35A	Jun 5	1130	PL	B-1		510	282	71	92.1	Jan 7(216)	Sep 29(116)	Military.
Kosmos 563	36A	Jun 6	1130	PL	A-2		320	213	65.4	89.5	Jun 18(12)	Jun 13(7)	Observation. Recovered. Separated a module.

Kosmos 564 Kosmos 565 Kosmos 566 Kosmos 567 Kosmos 568 Kosmos 569 Kosmos 570 Kosmos 571	37A 37B 37C 37D 37E 37F 37G 37H	Jun 8	1536	PL	C-1		1,507	1,392	74	114.5			Octuple launch. Possible communications satellites.
Kosmos 572	38A	Jun 10	1010	TT	A-2		294	211	51.7	89.3	Jun 23(13)	Jun 16(6)	Observation. Recovered. Separated a module.
Kosmos 573	41A	Jun 15	0600	TT	A-2	6570?	329	196	51.6	89.5	Jun 17(2)	Jun 21(6)	Manned precursor. Recovered.
Kosmos 574	42A	Jun 20	0617	PL	C-1		1,026	996	83	105			Possible navigation satellite.
Kosmos 575	43A	Jun 21	1150	PL	A-2		299	208	65.4	89.3	Jul 3(12)	Jul 17(20)	Observation. Recovered. Separated a module.
Kosmos 576	44A	Jun 27	1200	PL	A-2		356	212	72.9	89.9	Jul 9(12)	Jul 17(20)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	45B	Jul 11	0958	PL	A-2-e		463	221	65.4	91.4	Aug 22(42)	Aug 3(23)	Launched Molniya 2-6.
Molniya 2-6	45A						39,280	480	65.3	705			Communications satellite.
Tyazheliy Sputnik	47C	Jul 21	1931	TT	D-1-e		179	147	51.5	87.7	Jul 26(5)	Jul 23(2)	Launched Mars 4.
Mars 4	47A						1.57 au	0.99 au	2.2	530D			Passed Mars at 2200 kilometers Feb 10, 1974.
Kosmos 577	48A	Jul 25	1131	PL	A-2		312	209	65.4	89.5	Aug 7(13)	Aug 1(7)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	49C	Jul 25	1856	TT	D-1-e		174	159	51.6	87.8	Jul 27(2)	Jul 27(2)	Launched Mars 5.
Mars 5	49A						32,500	1,76 0	35	1500			Entered Mars orbit Feb. 12, 1974.
Kosmos 578	51A	Aug 1	1402	PL	A-2		308	207	65.4	89.4	Aug 13(12)	Aug 9(8)	Observation. Recovered.
Tyazheliy Sputnik	52C	Aug 5	1746	TT	D-1-e		193	154	51.5	87.9	Aug 7(2)	Aug 7(2)	Launched Mars 6.
Mars 6	52A						1.57 au	0.99 au	2.2	530D			Flew past Mars launching a lander.
Lander	52E												Missed Mars by 1300km.
Tyazheliy Sputnik	53C	Aug 9	1701	TT	D-1-e		193	154	51.5	87.9	Aug 11(2)	Aug 11(2)	Launched Mars 7.
Mars 7	53A						1.57 au	0.99 au	2.2	530D	Mar 12(215)		Flew past Mars launching a lander.
Lander	53E												Soft landed on Mars 24 S, 25 W.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Kosmos 579	55A	Aug 21	1229	PL	A-2		315	209	65.4	89.5	Sep 3(13)	Aug 28(7)	Observation. Recovered. Separated a module.
Kosmos 580	57A	Aug 22	1125	PL	B-1		518	283	71	92.2	Apr 1(222)	Nov 30(100)	Military.
Kosmos 581	59A	Aug 24	1100	TT	A-2		303	211	51.6	89.4	Sep 6(13)	Aug 31(7)	Observation. Recovered. Separated a module.
Kosmos 582	60A	Aug 28	1009	PL	C-1		559	521	74	95.3			Ferret.
Tyazheliy Sputnik	61C	Aug 30	0800	PL	A-2-e		481	223	65.4	91.6	Oct 8(39)	Oct 1(32)	Launched Molniya 1-24.
Molniya 1-24	61A						37,970	480	65.3	679			Communications satellite.
Kosmos 583	62A	Aug 30	1030	TT	A-2		316	208	65	89.5	Sep 12(13)	Sep 6(7)	Observation. Recovered. Separated a module.
Kosmos 584	63A	Sep 6	1040	PL	A-2		360	213	72.9	89.9	Sep 20(14)	Sep 17(11)	Observation. Recovered. Separated a module.
Kosmoa 585	64A	Sep 8	0150	PL	C-1		1,416	1,385	74	113.6			Possible navigation/geodetic satellite.
Koamos 586	65A	Sep 14	0032	PL	C-1		1,020	986	83	105			Possible navigation satellite.
Kosmos 587	66A	Sep 21	1305	PL	A-2		330	215	65.4	89.6	Oct 4(13)	Sep 28(7)	Observation. Recovered. Separated a module.
Soyuz 12	67A	Sep 27	1218	TT	A-2		345	326	51.6	91.2	Sep 29(2)	Sep 29(2)	Lazarev and Makarov Recovered.
Kosmos 588 Kosmos 589 Kosmos 590 Kosmos 591 Kosmos 592 Kosmos 593 Kosmos 594 Koamos 595	69A 69B 69C 69D 69E 69F 69G 69H	Oct 2	2146	PL	C-1		1,512	1,397	74	115	.		Octuple launch. Possible communications satellites.
Kosmos 596	70A	Oct 3	1300	PL	A-2		310	211	65.4	89.4	Oct 9(6)	Oct 9(6)	Observation. Recovered. Separated a module.
Kosmos 597	71A	Oct 6	1230	PL	A-2		312	212	65.4	89.5	Oct 12(6)	Oct 14(8)	Observation. Recovered. Separated a module.
Kosmoa 598	72A	Oct 10	1045	PL	A-2		360	213	72.9	90	Oct 16(6)	Oct 21(11)	Observation. Recovered. Separated a module.

Kosmos 599	73A	Oct 15	0845	TT	A-2	294	206	65	89.3	Oct 28(13)	Oct 21(6)	Observation. Recovered.
Kosmos 600	74A	Oct 16	1200	PL	A-2	366	215	72.9	90	Oct 23(7)	Oct 28(12)	Observation. Recovered. Separated a module.
Kosmos 601	75A	Oct 16	1450	PL	B-1	1,561	210	82	102.3	Aug 15(303)	Nov 6(21)	Military.
Tyazheliy Sputnik	76C	Oct 19	1026	PL	A-2-e	599	209	62.8	92.6	Dec 18(60)	Dec 3(45)	Launched Molniya 2-7.
Molniya 2-7	76A					40,600	630	62.8	736			Communications satellite.
Kosmos 602	77A	Oct 20	1015	PL	A-2	365	213	72.9	90	Oct 29(9)	Oct 31(11)	Observation. Recovered. Separated a module.
Kosmos 603	79A	Oct 27	1110	PL	A-2	380	214	72.9	90.1	Nov 9(13)	Nov 9(13)	Observation. Recovered. Separated a module.
Kosmos 604	80A	Oct 29	1401	PL	A-1	647	624	81.2	97.2			Ferret.
Interkosmos 10	82A	Oct 30	1900	PL	C-1	1,477	265	74	102			Ionospheric studies of particle concentrations, temperatures, magnetic fields.
Kosmos 605	83A	Oct 31	1825	PL	A-2	424	221	62.9	90.7	Nov 22(22)	Nov 28(28)	Biological. Recovered. Separated a module.
Tyazheliy Sputnik	84C	Nov 2	1302	PL	A-2-e	621	215	62.8	92.9	Jan 29(88)	Jan 6(65)	Launched Kosmos 606.
Kosmos 606	84A					39,360	626	62.8	710			Possible early warning.
Kosmos 607	87A	Nov 10	1240	PL	A-2	364	214	72.9	90	Nov 22(12)	Nov 23(13)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	89D	Nov 14	2040	TT	A-2-e	476	241	64.9	91.7	Jan 26(73)	Jan 2(49)	Launched Molniya 1-25.
Molniya 1-25	89A					39,140	480	65	702			Communications satellite.
Kosmos 608	91A	Nov 20	1230	PL	B-1	528	281	71	92.3	Jul 10(232)	Mar 23(123)	Military.
Kosmos 609	92A	Nov 21	1000	TT	A-2	370	207	70	90	Dec 4(13)	Dec 4(13)	Observation. Recovered. Separated a module.
Kosmos 610	93A	Nov 27	0008	PL	C-1	560	515	74	95.2			Ferret.
Kosmos 611	94A	Nov 28	1000	PL	B-1	507	280	71	92	Jun 19(203)	Mar 26(118)	Military.
Kosmos 612	95A	Nov 28	1143	PL	A-2	371	214	72.9	90.1	Dec 11(13)	Dec 12(14)	Observation. Recovered. Separated a module.
Kosmos 613	96A	Nov 30	0520	TT	A-2	396	255	51.6	91.0	Jan 29(60)	Dec 4(4)	Precursor to manned flight. Recovered.
Tyazheliy Sputnik	97C	Nov 30	1310	PL	A-2-e	440	207	62.8	91.0	Dec 31(31)	Dec 30(30)	Launched Molniya 1-26.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Molniya 1-26	97A						40,900	460	62.7	737			Communications satellite.
Kosmos 614	98A	Dec 4	1500	PL	C-1		830	770	74	100.7			Possible communications satellite.
Kosmos 615	99A	Dec 13	1110	PL	B-1		859	280	71	95.7	Dec 17(734)	Jan 24(407)	Military.
Kosmos 616	102A	Dec 17	1200	PL	A-2		355	214	72.9	89.9	Dec 28(11)	Dec 31(14)	Observation. Recovered. Separated a module.
Soyuz 13	103A	Dec 18	1155	TT	A-2		276	225	51.6	89.2	Dec 26(8)	Dec 22(4)	Klimuk and Lebedev. Recovered.
Kosmos 617 Kosmos 618 Kosmos 619 Kosmos 620 Kosmos 621 Kosmos 622 Kosmos 623 Kosmos 624	104A 104B 104C 104D 104E 104F 104G 104H	Dec 19	0944	PL	C-1		1,511	1,404	74	114.8			Octuple launch. Possible communications satellites.
Kosmos 625	105A	Dec 21	1843	PL	A-2		346	214	72.8	89.8	Jan 3(13)	Jan 1(11)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	106C	Dec 25	1117	PL	A-2-e		450	194	62.8	91.0	Jan 24(30)	Jan 17(23)	Launched Molniya 2-8.
Molniya 2-8	106A						40,865	466	62.8	737.0			Communications satellite.
Oreol 2	107A	Dec 26	1634	PL	C-1		1,995	407	74	109.2			Auroral studies.
Kosmos 626	108A	Dec 29	2024	TT	F-1-m		first 280 later 990	257 910	65 64.9	89.7 104.0		Feb 23(56)	Ocean surveillance satellite.
Kosmos 627	109A	Dec 29	0412	PL	C-1		1,032	991	83	105			Possible navigation satellite.
Kosmos 628	1974 1A	1974 Jan 17	1007	PL	C-1		1,026	975	83	105			Possible navigation satellite.
Kosmos 629	3A	Jan 24	1459	PL	A-2		315	202	62.8	89.9	Feb 5(12)	Feb 1(8)	Observation. Recovered. Separated a module.
Kosmos 630	4A	Jan 30	1100	PL	A-2		367	213	72.9	90	Feb 13(14)	Feb 14(15)	Observation. Recovered. Separated a module.
Kosmos 631	5A	Feb 6	0034	PL	C-1		565	522	74	95.3			Ferret.
Kosmos 632	6A	Feb 12	0856	TT	A-2		333	184	65	89.4	Feb 26(14)	Feb 17(5)	Observation. Recovered. Separated a module.

Kosmos 633	10A	Feb 27	1105	PL	B-3		516	280	71	92.2	Oct 4(219)	Jun 11(104)	Military.
Meteor 16	11A	Mar 5	1138	PL	A-1		906	853	81.2	102.2			Weather satellite.
Kosmos 634	12A	Mar 5	1605	PL	B-1		516	281	71	92.2	Oct 9(218)	Jun 17(104)	Military.
Kosmos 635	14A	Mar 14	1032	PL	A-2		350	212	72.9	89.8	Mar 26(12)	Mar 25(11)	Observation. Recovered. Separated a module.
Kosmos 636	16A	Mar 20	0830	TT	A-2		409	174	65	90	Apr 3(14)	Mar 24(4)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	17B	Mar 26	1335	TT	D-1-e		230	178	51.5	88.5	Mar 27(1)	Mar 28(2)	Launched Kosmos 637.
Kosmos 637	17A						35,600	35,600	0.25	1,426	•		Test of 24-hour synchronous technique.
Kosmos 638	18A	Apr 3	0730	TT	A-2	6570?	325	195	51.8	89.4	Apr 13(10)	Apr 9(6)	Precursor for manned flight - ASTP. Recovered.
Kosmos 639	19A	Apr 4	0838	PL	A-2		238	209	81.3	89	Apr 15(11)	Apr 7(3)	Observation. Recovered. Separated a module.
Kosmos 640	21A	Apr 11	1229	PL	A-2		236	205	81.3	88.9	Apr 23(12)	Apr 14(3)	Observation. Recovered. Possibly separated a module.
Tyazheliy Sputnik	23C	Apr 20	2053	PL	A-2-e		625	217	62.8	93.0	Jul 4(75)	Jun 20(61)	Launched Molniya 1-27.
Molniya 1-27	23A						40,713	646	62.9	738			Communications satellite.
Kosmos 641 Kosmos 642 Kosmos 643 Kosmos 644 Kosmos 645 Kosmos 646 Kosmos 647 Kosmos 648	24A 24B 24C 24D 24E 24F 24G 24H												Octuple launch. Possible communications satellites.
Meteor 17	25A	Apr 24	1150	PL	A-1		907	877	81.2	102.6			Weather satellite.
Tyazheliy Sputnik	26B	Apr 26	1423	PL	A-2-e		428	217	62.9	91.0	May 21(25)	May 17(21)	Launched Molniya 2-9.
Molniya 2-9	26A						40,850	463	62.9	737			Communications satellite.
Kosmos 649	27A	Apr 29	1329	PL	A-2		320	189	62.8	89.3	May 11(12)	May 3(4)	Observation. Recovered. Separated a module.
Kosmos 650	28A	Apr 29	1710	PL	C-1		1,413	1,380	74	113.5			Possible navigation/geodetic satellite.
Kosmos 651	29A	May 15	0730	TT	F-1-m	first later	276 954	256 892	65 65.0	89.6 103.5		Jul 30(76)	Ocean surveillance.
Kosmos 652	30A	May 15	0830	TT	A-2		362	180	51.8	89.6	May 23(8)	May 19(4)	Observation. Recovered. Separated a module.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Kosmos 653	31A	May 15	1230	PL	A-2		309	196	62.8	89.3	May 27(12)	May 20(5)	Observation. Recovered.
Kosmos 654	32A	May 17	0653	TT	F-1-m	first later	277 1,024	261 913	65 65.0	89.7 104.4		Aug 4(79)	Ocean surveillance.
Interkosmos 11	34A	May 17	1100	KY	C-1		526	484	50.7	94.5			Solar UV and X-ray studies.
Kosmos 655	35A	May 21	0606	PL	C-1		549	520	74	95.2			Ferret.
Kosmos 656	36A	May 27	0726	TT	A-2	6570?	354	194	51.6	89.7	May 29(2)	Jun 2(6)	Precursor to manned flight.
Tyazheliy Sputnik	37C	May 29	0857	TT	D-1-e		227	178	51.6	88.5	Jun 2(4)	Jun 2(4)	Launched Luna 22.
Luna 22	37A					first later	249 1,409	25 200	 21	 192			Returned pictures from lunar orbit.
Kosmos 657	38A	May 30	1245	PL	A-2		317	182	62.8	89.2	Jun 13(14)	Jun 2(3)	Observation. Recovered. Separated a module.
Kosmos 658	41A	Jun 6	0620	TT	A-2		304	206	65	89.4	Jun 18(12)	Jun 12(6)	Observation. Recovered.
Kosmos 659	43A	Jun 13	1230	PL	A-2		360	190	62.8	89.7	Jun 26(13)	Jun 18(3)	Observation. Recovered. Separated a module.
Kosmos 660	44A	Jun 18	1300	PL	C-1		1,995	409	83	109.2			Military.
Kosmos 661	45A	Jun 21	0930	PL	C-1		555	513	74	95			Ferret.
Salyut 3	46A	Jun 24	2238	TT	D-1	18,900?	292	256	51.6	89.9	Jan 24(215)	Jul 3(9)	Military space station.
Kosmos 662	47A	Jun 26	1230	PL	B-[illegible]		838	282	71	95.5		Oct 26(122)	Military.
Kosmos 663	48A	Jun 27	1540	PL	C-1		1,017	983	83	105			Possible navigation satellite.
Kosmos 664	49A	Jun 29	1205	PL	A-2		364	212	72.9	90	Jul 11(12)	Jul 9(10)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	50B	Jun 29	1600	PL	A-2-e		610	216	62.8	92.8	Sep 1(64)	Aug 13(45)	Launched Kosmos 665.
Kosmos 665	50A						39,384	633	62.9	710			Possible early warning satellit
Soyuz 14	51A	Jul 3	1851	TT	A-2	6570?	277	255	51.6	89.7	Jul 19(16)	Jul 5(2)	Popovich, Artyukhin. Recovered. Entered Salyut 3.
Meteor 18	52A	Jul 9	1440	PL	A-1		905	877	81.2	102.6			Weather satellite.

Kosmos 666	53A	Jul 12	1250	PL	A-2		351	191	62.8	89.6	Jul 25(13)	Jul 18(6)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	56C	Jul 23	0123	PL	A-2-e		451	216	62.8	91.2	Aug 28(36)	Aug 26(34)	Launched Molniya 2-10.
Molniya 2-10	56A						40,900	460	62.8	737			Communications satellite.
Kosmos 667	57A	Jul 25	0700	TT	A-2		342	182	65	89.5	Aug 7(13)	Jul 30(5)	Observation. Recovered. Separated a module.
Kosmos 668	58A	Jul 25	1200	PL	B-1		519	281	71	92.2	Feb 21(211)	Nov 15(113)	Military.
Kosmos 669	59A	Jul 26	0700	PL	A-2		244	210	81.3	88.9	Aug 8(13)	Jul 30(4)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	60B	Jul 29	1200	TT	D-1-e		195	183	51.5	88.2	Aug 1(3)	Jul 31(2)	Launched Molniya 1-S-1.
Molniya 1-S-1	60A						35,850	35,850	0.07	1,439			Communications satellite.
Kosmos 670	61A	Aug 6	0907	TT	A-2	6570?	307	217	50.6	89.5	Aug 9(3)	Aug 13(7)	Precursor to manned flight. Recovered.
Kosmos 671	62A	Aug 7	1259	PL	A-2		369	191	62.8	89.7	Aug 20(13)	Aug 14(7)	Observation. Recovered. Separated a module.
Kosmos 672	64A	Aug 12	0625	TT	A-2	6570?	221	195	51.8	88.6	Aug 18(6)	Aug 14(2)	Precursor to manned flight - ASTP. Recovered.
Kosmos 673	66A	Aug 16	0343	PL	A-1		648	620	81.2	97			Ferret.
Soyuz 15	67A	Aug 26	1958	TT	A-2	6570?	275	254	51.6	89.6	Aug 28(2)	Aug 28(2)	Sarafanov, Demin. Recovered. Unable to dock to Salyut 3.
Kosmos 674	68A	Aug 29	0740	TT	A-2		343	182	65	89.5	Sep 7(9)	Sep 4(6)	Observation. Recovered. Separated a module.
Kosmos 675	69A	Aug 29	1445	PL	C-1		1,429	1,370	74	113.7			Possible navigation/geodetic satellite.
Kosmos 676	71A	Sep 11	1740	PL	C-1		840	799	74	101			Possible communications satellite.
Kosmos 677 Kosmos 678 Kosmos 679 Kosmos 680 Kosmos 681 Kosmos 682 Kosmos 683 Kosmos 684	72A 72B 72C 72D 72E 72F 72G 72H	Sep 19	1457	PL	C-1		1,519	1,451	74	115.5			Octuple launch. Possible communications satellites.
Kosmos 685	73A	Sep 20	0936	TT	A-2		303	208	65	89.4	Oct 2(12)	Sep 26(6)	Observation. Recovered.
Kosmos 686	74A	Sep 26	1635	PL	B-1		515	281	71	92.2	May 1(217)	Oct 29(33)	Military.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Kosmos 687	76A	Oct 11	1130	PL	C-1		717	292	74	94.5			Military.
Kosmos 688	78A	Oct 18	1505	PL	A-2		371	188	62.8	89.8	Oct 30(12)	Oct 24(6)	Observation. Recovered. Separated a module.
Kosmos 689	79A	Oct 18	2236	PL	C-1		1,032	992	83	105.1			Possible navigation satellite.
Kosmos 690	80A	Oct 22	1800	PL	A-2		389	223	62.8	90.4	Nov 12(21)	Nov 10(19)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	81C	Oct 24	1240	PL	A-2-e		658	211	62.8	93.3	Jan 3(71)	Dec 31(68)	Launched Molniya 1-28.
Molniya 1-28	81A						40,617	683	62.8	736			Communications satellite.
Kosmos 691	82A	Oct 25	0930	TT	A-2		352	180	65	89.5	Nov 6(12)	Oct 29(4)	Observation. Recovered. Separated a module.
Meteor 19	83A	Oct 28	1019	PL	A-1		917	855	81.2	102.5			Weather satellite.
Tyazheliy Sputnik	84B	Oct 28	1430	TT	D-1-e		246	183	51.5	88.7	Nov 1(4)	Nov 1(4)	Launched Luna 23.
Luna 23	84A						105	17	138	1.04	Nov 6(9)	unknown	Damaged in landing on Moon. Unable to return sample.
Returner	84E												
Interkosmos 12	86A	Oct 31	1000	PL	C-1		708	264	74.1	94.1	Jul 11(253)	Jul 23(265)	Ionospheric and atmospheric studies.
Kosmos 692	87A	Nov 1	1420	PL	A-2		315	201	62.8	89.4	Nov 13 (12)	Nov 6(5)	Observation. Recovered. Separated a module.
Kosmos 693	88A	Nov 4	1040	PL	A-2		271	215	81.3	89.1	Nov 16(12)	Nov 9(5)	Observation. Recovered. Separated a module.
Kosmos 694	90A	Nov 16	1145	PL	A-2		344	213	72.9	89.8	Nov 29(13)	Nov 25(9)	Observation. Recovered. Separated a module.
Kosmos 695	91A	Nov 20	1200	PL	B-1		493	283	71	92	Jul 15(237)	Mar 15(115)	Military.
Tyazheliy Sputnik	92C	Nov 21	1033	PL	A-2-e		626	201	62.8	92.8	Jan 11(51)	Jan 27(67)	Launched Molniya 3-1.
Molniya 3-1	92A						40,690	650	62.8	732			Communications satellite.
Kosmos 696	95A	Nov 27	1145	PL	A-2		345	212	72.9	89.8	Dec 9(12)	Dec 5(8)	Observation. Recovered.
Soyuz 16	96A	Dec 2	0940	TT	A-2	6570?	225	225	51.8	88.9	Dec 8(12)	Dec 7(5)	Filipchenko, Rukovishnikov. Recovered. ASTP test.

Kosmos 697	98A	Dec 13	1331	PL	A-2		415	182	62.8	90.2	Dec 25(12)	Dec 21(8)	Observation. Recovered. Separated a module.
Meteor 20	99A	Dec 17	1145	PL	A-1		910	861	81.2	102.4			Weather satellite.
Kosmos 698	100A	Dec 18	1412	PL	C-1		566	515	74	95.3			Ferret.
Tyazheliy Sputnik	102C	Dec 21	0220	PL	A-2-e		626	211	62.8	92.9	Mar 8(77)	Mar 12(81)	Launched Molniya 2-11.
Molniya 2-11	102A						40,675	641	62.9	737			Communications satellite.
Kosmos 699	103A	Dec 24	1100	TT	F-1-m		454	436	65	93.2		Dec 25(1)	Military. Possible ferret.
Salyut 4	104A	Dec 26	0415	TT	D-1	18,900?	355	343	51.6	91.3		Jan 1(6)	Civilian space station.
Kosmos 700	105A	Dec 26	1200	PL	C-1		1,012	976	83	105			Possible navigation satellite.
Kosmos 701	106A	Dec 27	0910	TT	A-2		339	210	71.4	89.8	Jan 9(13)	Jan 7(11)	Observation. Recovered. Separated a module.
	<u>1975</u>	<u>1975</u>											
Soyuz 17	1A	Jan 10	2143	TT	A-2	6570?	355	342	51.6	91.3	Feb 9(30)	Jan 14(4)	Gubarev, Grechko. Recovered. Occupied Salyut 4.
Kosmos 702	2A	Jan 17	0907	TT	A-2		334	210	71.4	89.7	Jan 29(12)	Jan 29(12)	Observation. Recovered.
Kosmos 703	3A	Jan 21	1102	PL	B-1		1,545	207	82	102	Nov 20(303)	Aug 22(213)	Military.
Kosmos 704	5A	Jan 23	1102	PL	A-2		329	213	72.9	89.6	Feb 6(14)	Feb 3(11)	Observation. Recovered. Separated a module.
Kosmos 705	6A	Jan 28	1200	PL	B-1		524	281	71	92.3	Nov 18(294)	Jun 25(148)	Military.
Tyazheliy Sputnik	7C	Jan 30	1508	PL	A-2-e		629	179	62.9	92.6	Mar 2(31)	Apr 4(64)	Launched Kosmos 706.
Kosmos 706	7A						39,812	635	62.8	719			Possible early warning satellite.
Kosmos 707	8A	Feb 5	1412	PL	C-1		550	505	74	95.2			Ferret.
Tyazheliy Sputnik	9C	Feb 6	0448	PL	A-2-e		620	212	62.8	92.9	Apr 23(76)	Apr 25(78)	Launched Molniya 2-12.
Molniya 2-12	9A						40,685	640	62.8	737			Communications satellite.
Kosmos 708	12A	Feb 12	0322	PL	C-1		1,423	1,387	69.2	113.6			Possible navigation/geodetic satellite.
Kosmos 709	13A	Feb 12	0832	PL	A-2		333	188	62.8	89.4	Feb 25(13)	Feb 17(5)	Observation. Recovered. Separated a module.
Kosmos 710	15A	Feb 26	0907	TT	A-2		355	180	65	89.6	Mar 12(14)	Mar 3(5)	Observation. Recovered. Separated a module.

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Kosmos 711 Kosmos 712 Kosmos 713 Kosmos 714 Kosmos 715 Kosmos 716 Kosmos 717 Kosmos 718	16A 16B 16C 16D 16E 16F 16G 16H	Feb 28	1402	PL	C-1		1,530	1,449	74	115.5			Octuple launch. Possible communications satellites.
Kosmos 719	18A	Mar 12	0855	TT	A-2		329	182	65	89.3	Mar 25(13)	Mar 16(4)	Observation. Recovered. Separated a module.
Kosmos 720	19A	Mar 21	0650	PL	A-2		283	223	62.8	89.4	Apr 1(11)	Mar 30(9)	Observation. Recovered. Separated a module.
Kosmos 721	20A	Mar 26	0851	PL	A-2		241	210	81.3	88.9	Apr 7(12)	Mar 29(3)	Observation. Recovered. Separated a module.
Kosmos 722	21A	Mar 27	0800	TT	A-2		359	210	71.4	89.9	Apr 9(13)	Apr 9(13)	Observation. Recovered. Separated a module.
Interkosmos 13	22A	Mar 27	1430	PL	C-1		1,714	296	83	104.9			Magnetosphere and polar ionospheric studies.
Meteor 21	23A	Apr 1	1230	PL	A-1		906	877	81.2	102.6			Weather satellite.
Kosmos 723	24A	Apr 2	1100	TT	F-1-m	first later	277 951	256 916	65 65.0	89.6 103.7		May 21(49)	Possible ocean surveillance satellite.
Soyuz		Apr 5		TT	A-2		200 up	1,60 0 away	51.6	20			Lazarev, Makarov. Recovered. Launch aborted.
Kosmos 724	25A	Apr 7	1100	TT	F-1-m	first later	276 938	258 86 8	65 65.5	89.7 103.0		Aug 7(122)	Possible ocean surveillance satellite.
Kosmos 725	26A	Apr 8	1830	PL	B-1		508	283	71	92.1	Jan 6(273)	Sep 9(154)	Military.
Kosmos 726	28A	Apr 11	0758	PL	C-1		1,008	972	83	104.7			Possible navigation satellite.
Tyazheliy Sputnik	29C	Apr 14	1753	PL	A-2-e		593	196	62.9	92.4	Jun 4(51)	Jun 20(67)	Launched Molniya 3-2.
Molniya 3-2	29A						40,660	636	63	736			Communications satellite.
Kosmos 727	30A	Apr 16	0800	TT	A-2		358	180	65	89.6	Apr 28(12)	Apr 21(5)	Observation. Recovered. Separated a module.
Kosmos 728	31A	Apr 18	1000	PL	A-2		350	211	72.8	89.8	Apr 29(11)	Apr 30(12)	Observation. Recovered. Separated a module.

Ariabat	33A	Apr 19	0730	KY	C-1	619	563	50.7	96.3			Indian Science. X-ray astronomy, solar radiation, ionospheric studies.
Kosmos 729	34A	Apr 22	2107	PL	C-1	1,023	995	83	105			Possible navigation satellite.
Kosmos 730	35A	Apr 24	0805	PL	A-2	251	212	81.3	39	May 6(12)	Apr 29(5)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	36C	Apr 29	1025	PL	A-2-e	459	210	62.8	91.2	Jun 3(35)	May 29(30)	Launched Molniya 1-29.
Molniya 1-29	36A					40,848	468	63	737			Communications satellite.
Kosmos 731	41A	May 21	0700	TT	A-2	313	207	65	89.5	Jun 2(12)	May 30(9)	Observation. Recovered. Separated a module.
Soyuz 18	44A	May 24	1458	TT	A-2	356	344	51.6	91.3	Jul 26(63)	May 27(3)	Klimuk, Sevastyanov. Recovered. Occupied Salyut 4.
Kosmos 732	45A	May 28	0025	PL	C-1	1,532	1,475	74	115.8			Octuple launch. Possible communications satellites.
Kosmos 733	45B											
Kosmos 734	45C											
Kosmos 735	45D											
Kosmos 736	45E											
Kosmos 737	45F											
Kosmos 738	45G											
Kosmos 739	45H											
Kosmos 740	46A	May 28	0730	TT	A-2	347	181	65	89.5	Jun 10(13)	Jun 3(6)	Observation. Recovered. Separated a module.
Kosmos 741	47A	May 30	0648	PL	A-2	246	210	81.4	89	Jun 11(12)	Jun 4(5)	Observation. Recovered.
Kosmos 742	48A	Jun 3	1321	PL	A-2	375	189	62.8	89.8	Jun 15(12)	Jun 11(8)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	49C	Jun 5	0138	PL	A-2-e	424	213	62.8	90.9	Jul 16(11)	Jul 8(3)	Launched Molniya 1-30 and MAS-2.
Molniya 1-30	49A					40,890	450	63	737			Communications satellite.
MAS-2	49B					40,890	450	63	737			French engineering test.
Tyazheliy Sputnik	50C	Jun 8	0237	TT	D-1-e	196	171	51.5	88.1	Jun 9(1)	Jun 9(1)	Launched Venera 9.
Venera 9	50A					112,330						Orbited Venus gathering data.
Lander	50D									Oct 22(136)		Landed on Venus, returned picture.
Kosmos 743	53A	Jun 12	1230	PL	A-2	355	190	62.8	89.6	Jun 25(13)	Jun 20(8)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	54C	Jun 14	0300	TT	D-1-e	206	162	51.5	88.1	Jun 15(1)	Jun 15(1)	Launched Venera 10.

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Venera 10	54A						114,100						Orbited Venus, gathering data.
Lander	54D										Oct 25(133)		Landed on Venus, returned a picture.
Kosmos 744	56A	Jun 20	0654	PL	A-1		650	612	81.2	97.1			Ferret.
Kosmos 745	58A	Jun 24	1205	PL	B-1		540	274	71	92.4		Nov 14(143)	Military.
Kosmos 746	59A	Jun 25	1258	PL	A-2		346	188	62.8	89.5	Jul 8(13)	Jul 1(7)	Observation. Recovered. Separated a module.
Kosmos 747	60A	Jun 27	1300	PL	A-2		309	197	62.8	89.3	Jul 9(12)	Jul 3(6)	Observation. Recovered. Separated a module.
Kosmos 748	61A	Jul 3	1340	PL	A-2		339	184	62.8	89.5	Jul 16(13)	Jul 9(6)	Observation. Recovered. Separated a module.
Kosmos 749	62A	Jul 4	0056	PL	C-1		557	511	74	95.3			Ferret.
Tyazheliy Sputnik	63C	Jul 8	0505	PL	A-2-e		445	204	62.8	91.0	Aug 9(32)	Aug 9(32)	Launched Molniya 2-13.
Molniya 2-13	63A						40,864	465	62.8	737			Communications satellite.
Meteor 2-1	64A	Jul 11	0415	PL	A-1		903	872	81.3	102.5			Experimental weather satellite.
Soyuz 19	65A	Jul 15	1220	TT	A-2	5,800	225	223	51.8	88.9	Jul 21(6)	Jul 17(2)	Leonov, Kubasov recovered. Docked with Apollo.
Kosmos 750	67A	Jul 17	0907	PL	B-1		830	281	71	95.4			Military.
Kosmos 751	68A	Jul 23	1300	P	A-2		335	203	62.8	89.6	Aug 4(12	Jul 30(7)	Observation. Recovered.
Kosmos 752	69A	Jul 24	1900	PL	C-1		526	480	65.9	94.6			Military.
Kosmos 753	71A	Jul 31	1300	PL	A-2		351	189	62.8	89.6	Aug 13(13)	Aug 7(7)	Observation. Recovered. Separated a module.
Kosmos 754	73A	Aug 13	0721	TT	A-2		345	210	71.4	89.8	Aug 26(13)	Aug 25(12)	Observation. Recovered. Separated a module.
Kosmos 755	74A	Aug 14	1329	PL	C-1		1,025	991	82.9	105			Possible navigation satellite.
Kosmos 756	76A	Aug 22	0211	PL	A-1		649	627	81.2	97.3			Ferret.
Kosmos 757	78A	Aug 27	1445	PL	A-2		337	190	62.8	89.5	Sep 9(13)	Sep 3(7)	Observation. Recovered. Separated a module.

Tyazheliy Sputnik	79C	Sep 2	1309	PL	A-2-e		613	206	62.8	92.8	Nov 1(60)	Nov 10(69)	Launched Molniya 1-31.
Molniya 1-31	79A						40,681	639	62.8	737			Communications satellite.
Kosmos 758	80A	Sep 5	1451	PL	A-2		351	181	67.2	89.5	Sep 25(20)	Sep 10(5)	Observation. No recovery. Exploded.
Tyazheliy Sputnik	81C	Sep 9	0019	PL	A-2-e		459	213	62.8	91.2	Oct 18(39)	Oct 9(30)	Launched Molniya 2-14.
Molniya 2-14	81A						40,836	470	62.8	736			Communications satellite.
Kosmos 759	84A	Sep 12	0530	PL	A-2		281	234	62.8	89.6	Sep 23(11)	Sep 25(13)	Observation. Recovered. Separated a module.
Kosmos 760	85A	Sep 16	0900	TT	A-2		355	181	65	90.6	Sep 30(14)	Sep 21(5)	Observation. Recovered. Separated a module.
Kosmos 761	86A	Sep 17	0710	PL	C-1		1,537	1,454	74	115.5			Octuple launch. Possible communications satellites.
Kosmos 762	86B												
Kosmos 763	86C												
Kosmos 764	86D												
Kosmos 765	86E												
Kosmos 766	86F												
Kosmos 767	86G												
Kosmos 768	86H												
Meteor 1-22	87A	Sep 18	0020	PL	A-1		918	867	81.2	102.3			Weather satellite.
Kosmos 769	88A	Sep 23	1000	PL	A-2		331	211	72.9	89.6	Oct 5(12)	Oct 2(()	Observation. Recovered. Separated a module.
Kosmos 770	89A	Sep 24	1200	PL	C-1		1,222	1,188	83	109.2			Possible navigation/geodetic satellite.
Kosmos 771	90A	Sep 25	0750	PL	A-2		247	219	81.3	88.9	Oct 8(13)	Sep 29(4)	Observation. Recovered. Separated a module.
Kosmos 772	93A	Sep 29	0420	TT	A-2	6570?	320	201	51.8	89.4	Oct 2(3)	Oct 6(7)	Precursor to manned flight.
Kosmos 773	94A	Sep 30	1838	P	C-1		828	79 1	74.1	100.9			Possible communications satellite.
Kosmos 774	95A	Oct 1	0830	TT	A-2		333	212	71.4	89.7	Oct 15(14)	Oct 10(9)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	97B	Oct 8	0030	TT	D-1-e		205	178	51.5	88.3	Oct 10(2)	Oct 9(1)	Launched Kosmos 775.
Kosmos 775	97A						35,900	35,900	0.1	1,442			Possible early warning satellite.
Kosmos 776	101 A	Oct 17	1430	PL	A-2		310	203	62.8	89.4	Oct 29(12)	Oct 23(6)	Observation. Recovered. Separated a module.
Kosmos 777	102A	Oct 29	1103	TT	F-1-m		456	437	65	93.3		Oct 30(1)	Possible ferret.

Name	Int'l Desig	Date	Hour	Site	Vehicle	(KG) Weight	(KM) Apogee	(KM) Perigee	(degrees) Inclin	(min) Period	Payload Decay Date & Life	Carrier Rocket Decay Date & Life	Mission and Remarks
Kosmos 778	103A	Nov 4	1013	PL	C-1		1,018	989	83	104.9			Possible navigation satellite.
Kosmos 779	104A	Nov 4	1522	PL	A-2		334	188	62.8	89.4	Nov 18(14)	Nov 10(6)	Observation. Recovered. Separated a module.
Tyazheliy Sputnik	105C	Nov 14	1914	PL	A-2-e		451	191	62.8	90.9	Dec 5(21)	Dec 15(31)	Launched Molniya 3-3.
Molniya 3-3	105A						40,930	470	62.4	736			Communications satellite.
Soyuz 20	106A	Nov 17	1437	TT	A-2		367	343	51.6	91.4		Nov 20(3)	Unmanned. Docked with Salyut 4. Biological experiments.
Kosmos 780	108A	Nov 21	0920	TT	A-2		298	206	65	89.3	Dec 3(12)	Nov 27(6)	Observation. Recovered. Separated a module.
Kosmos 781	109A	Nov 21	1711	PL	C-1		557	508	74	95.2			Ferret.
Kosmos 782	110A	Nov 25	1700	PL	A-2		405	227	62.8	90.5	Dec 15(20)	Dec 23(28)	Biological payload. Recovered.
Kosmos 783	112A	Nov 28	0011	PL	C-1		838	797	74	101			Possible communications satellite.
Kosmos 784	113A	Dec 3	1000	PL	A-2		252	216	81.3	89	Dec 15(12)	Dec 7(4)	Observation. Recovered. Separated a module.
Interkosmos 14	115A	Dec 11	1700	PL	C-1		1,707	345	74	105.3			Electromagnetic fluctuations, ionospheric structure.
Kosmos 785	116A	Dec 12	1243	TT	F-1-m	first later	278 1,023	259 898	65 65.1	89.7 104.3			Possible ocean surveillance satellite.
Kosmos 786	120A	Dec 16	0950	TT	A-2		346	180	65	89.5	Dec 29(13)		Observation. Recovered. Separated a module.
Tyazheliy Sputnik	121C	Dec 17	1106	P	A-2-e		433	196	62.8	90.8	Jan 11(25)		Launched Molniya 2-15.
Molniya 2-15	121A						40,836	451	62.8	736			Communications satellite.
Tyazheliy Sputnik	122C	Dec 22	0209	TT	A-2-e		498	209	65.0	91.6			Launched Prognoz 4.
Prognoz 4	122A					905	199,000	634	65	5,740			Solar radiation studies.
Tyazheliy Sputnik	123B	Dec 22	1300	TT	D-1-e		197	146	51.5	87.9	Dec 22(0)	Dec 25(3)	Launched Raduga 1.
Raduga 1	123A						35,800	35,800	0.3	1,434			Communications satellite.
Meteor 1-23	124A	Dec 25	1900	PL	A-1		913	857	81.3	102.4			Weather satellite.
Tyazheliy Sputnik	125C	Dec 27	1022	PL	A-2-e		449	194	62.8	90.9			Launched Molniya 3-4.
Molniya 3-4	125A						40,800	470	62.8	736			Communications satellite.

APPENDIX B

ILLUSTRATIONS OF SOVIET LAUNCH VEHICLES AND SPACECRAFT

Drawings have been done by Charles S. Sheldon II, except where noted as prepared by D. R. Woods and C. P. Vick. Mr. Woods holds a copyright on his drawings and he has made them available for this limited use in the report. Thanks are extended to Mr. Woods and Mr. Vick for their investment of time and skill and research to make available the material from them which has been used.

While the drawings which follow have been grouped to reflect such broad categories as launch vehicles, scientific Earth satellites, applications satellites, lunar payloads, Venus payloads, Mars payloads, and man-related payloads, there is some supplementary information as well. Mr. Woods attempted a limited comparison in graphic form of the ability of U.S. and Soviet launch vehicles to attain certain velocities and altitudes or distances with various weights of payload. Also, there are representations included of the principal types of Soviet space and missile tracking or support ships.

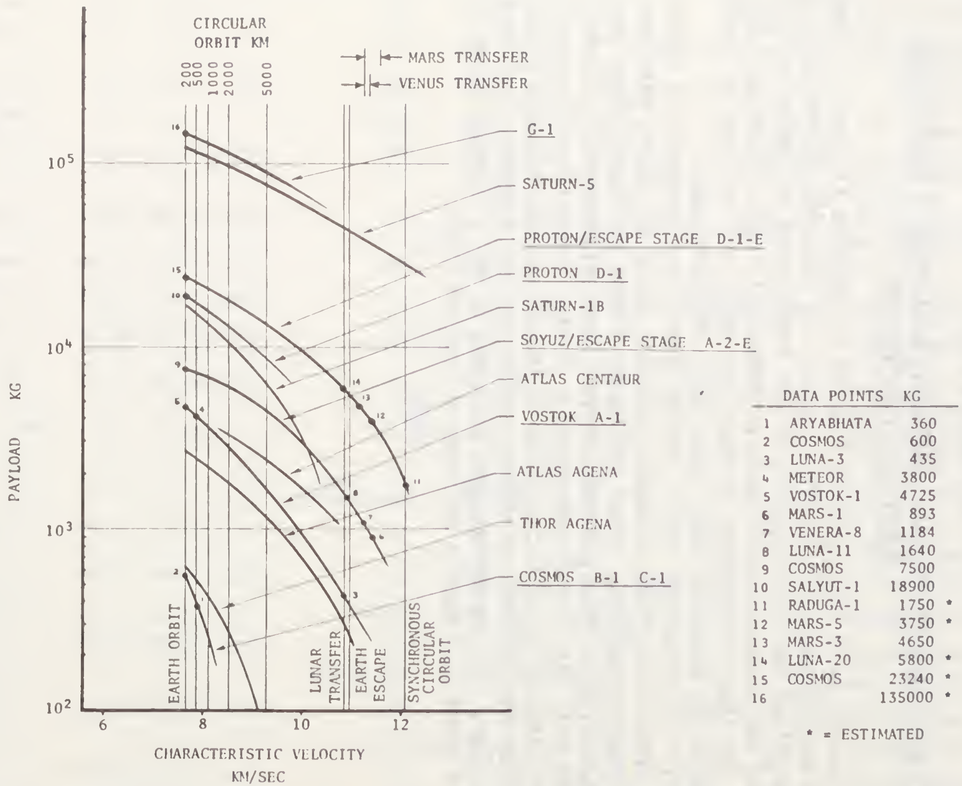

FIGURE 1.—Approximate performance characteristics of Soviet and American space launch vehicles (prepared by D. R. Woods). Essentially correct, but does not reflect the greater lifting capacity of the C-1 over the B-1.

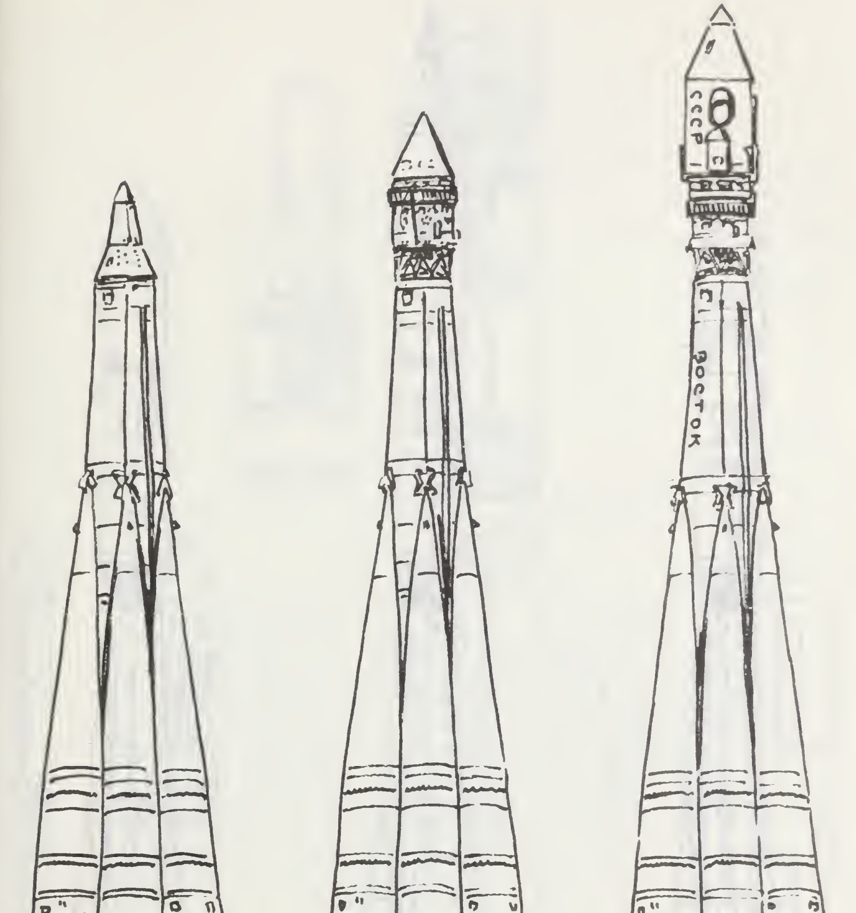

FIGURE 2.—Left: Soviet launch vehicle A, with early Sputnik payload. Center: Soviet A-1 launch vehicle with early Luna payload. Right: Soviet A-1 launch vehicle with Vostok payload.

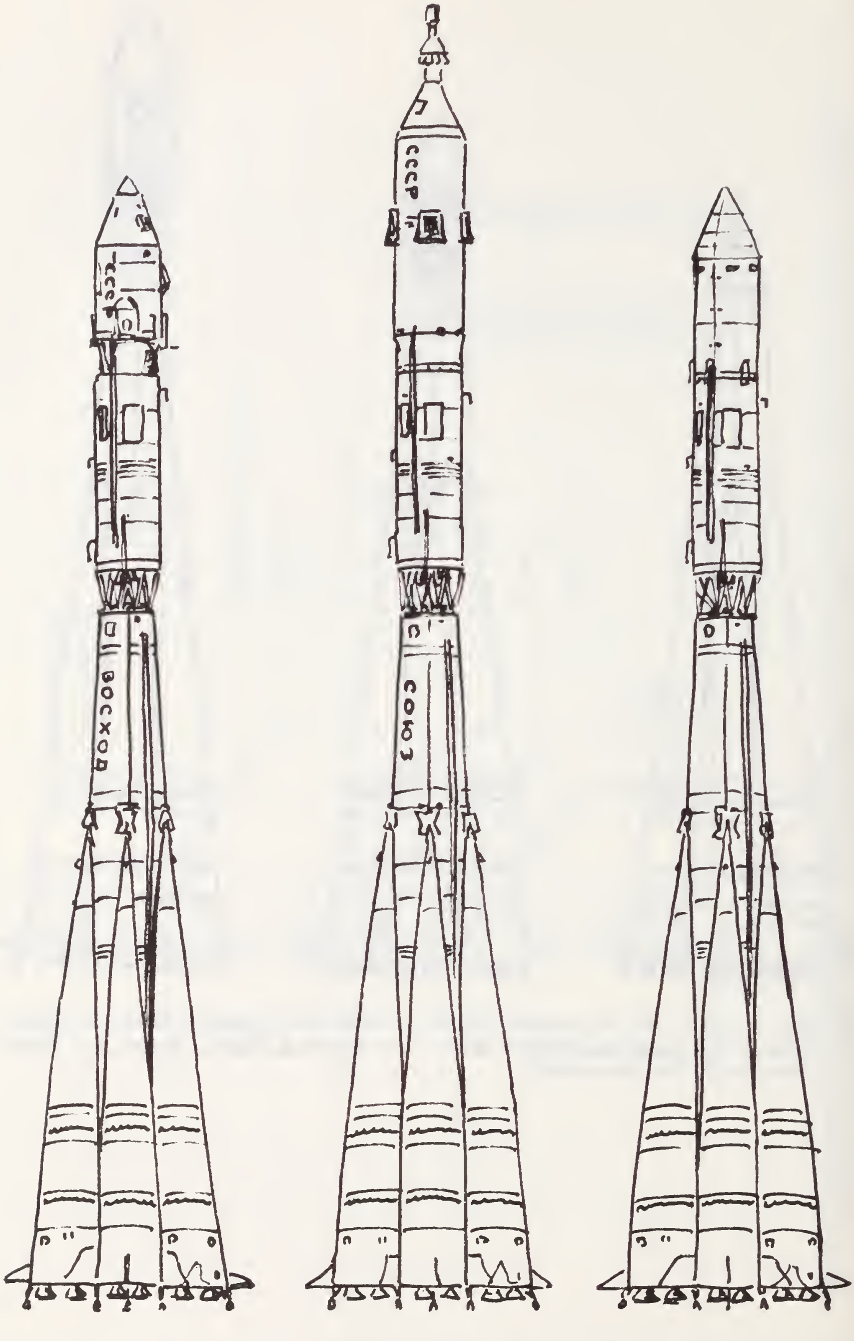

FIGURE 3.—Left: Soviet A–2 launch vehicle with Voskhod payload. Center: Soviet A–2 launch vehicle with Soyuz payload. Right: Soviet A–2–e launch vehicle with deep space payload.

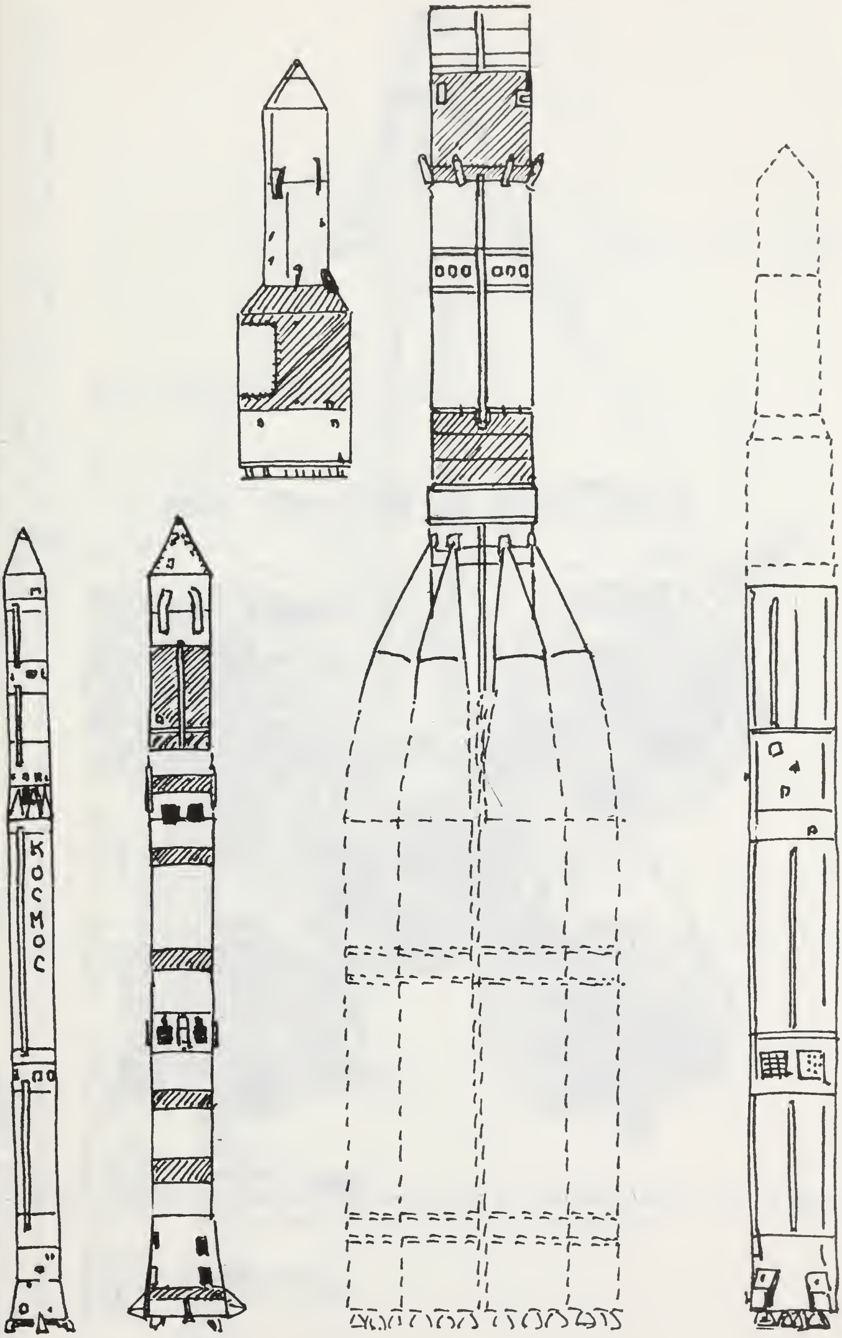

FIGURE 4.—Left: Soviet B–1 launch vehicle with small Kosmos payload. Left center: Soviet C–1 launch vehicle with intermediate Kosmos payload. Right center: Soviet D–1 launch vehicle (lower stages only postulated); the payload portion, a Salyut space station to mount on top is shown adjacent. Right: Soviet F–1–m launch vehicle (upper stages only postulated), for a variety of military maneuverable flights.

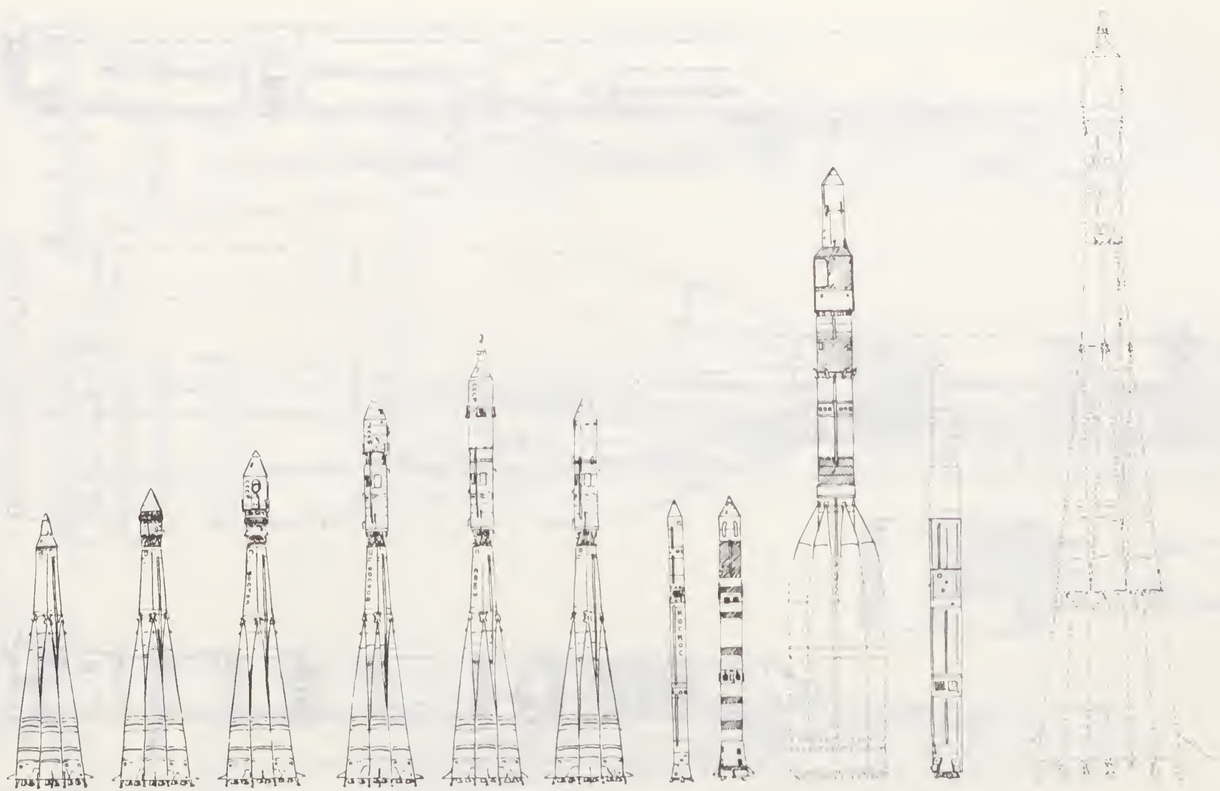

FIGURE 5.—Vehicles representative of the entire stable of Soviet launch vehicles for orbital and escape flights. The vehicle farthest to the right does not represent any actual configuration of the G–1–e, but suggests the approximate size of the big vehicle if it

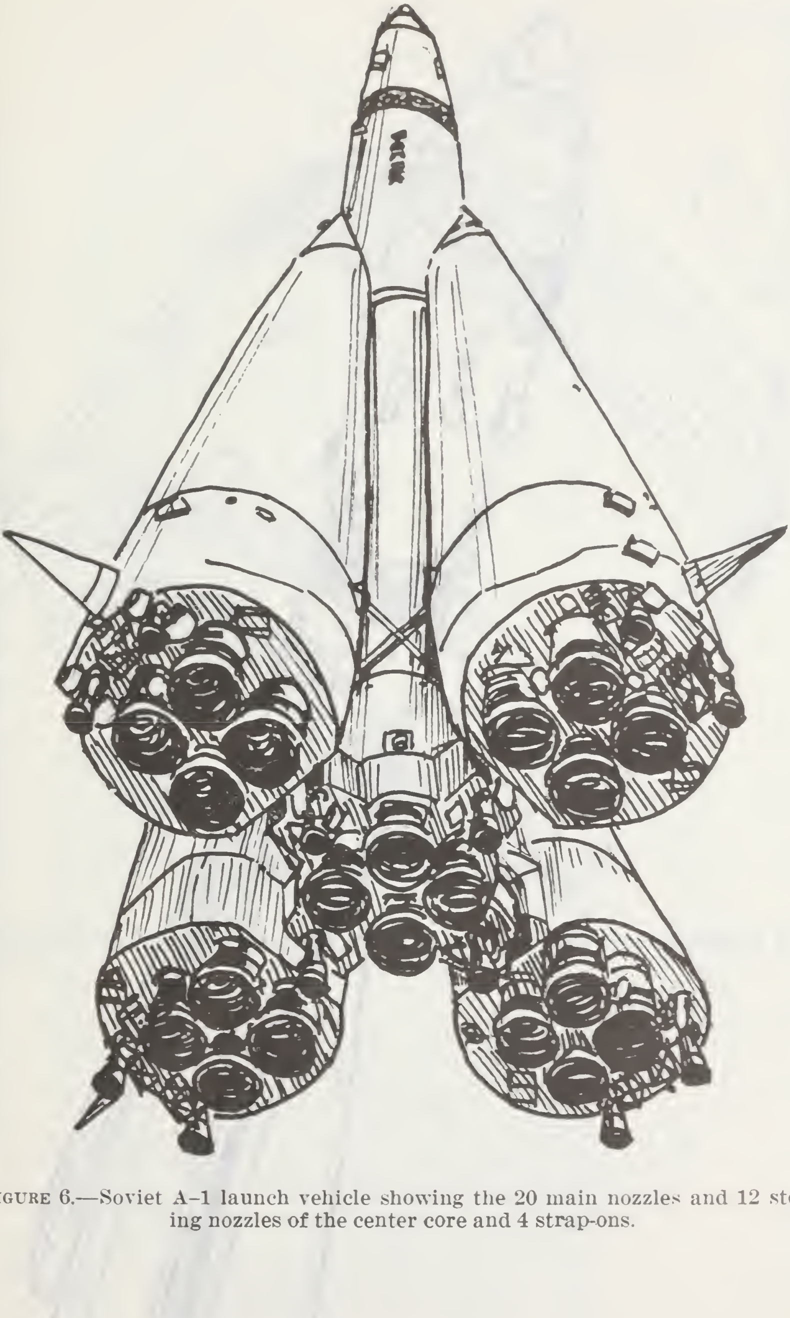

FIGURE 6.—Soviet A–1 launch vehicle showing the 20 main nozzles and 12 steering nozzles of the center core and 4 strap-ons.

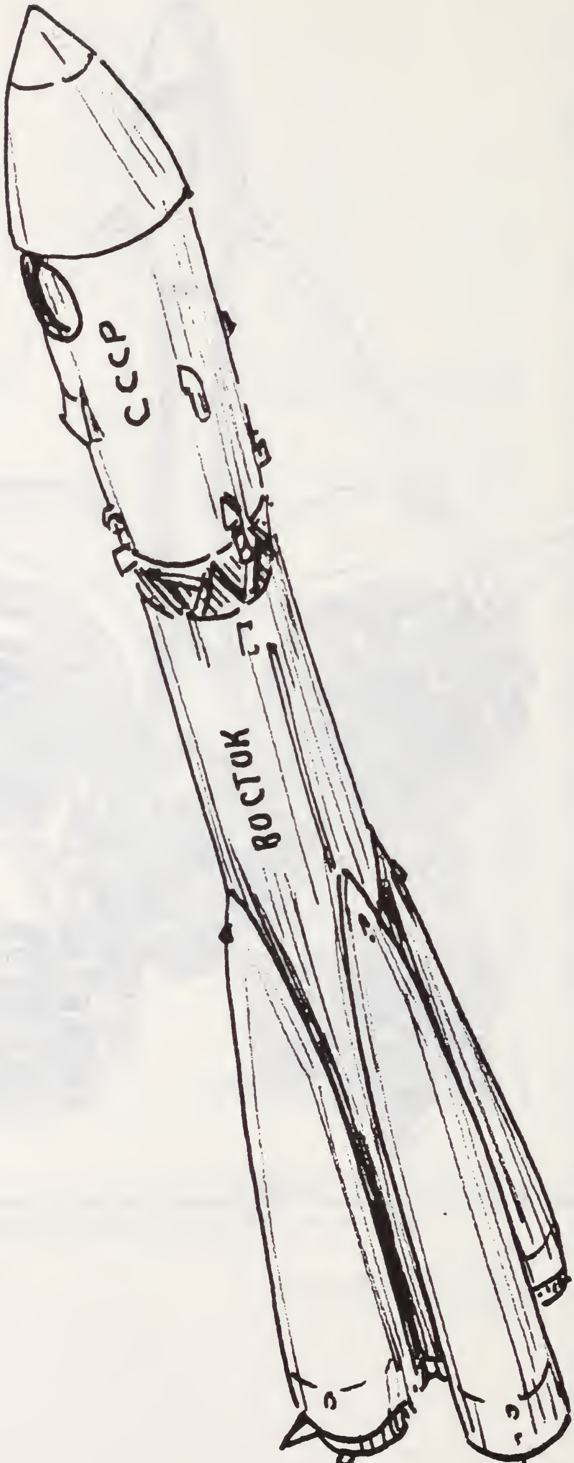

FIGURE 7.—Soviet A-1 launch vehicle with Vostok payload in its shroud.

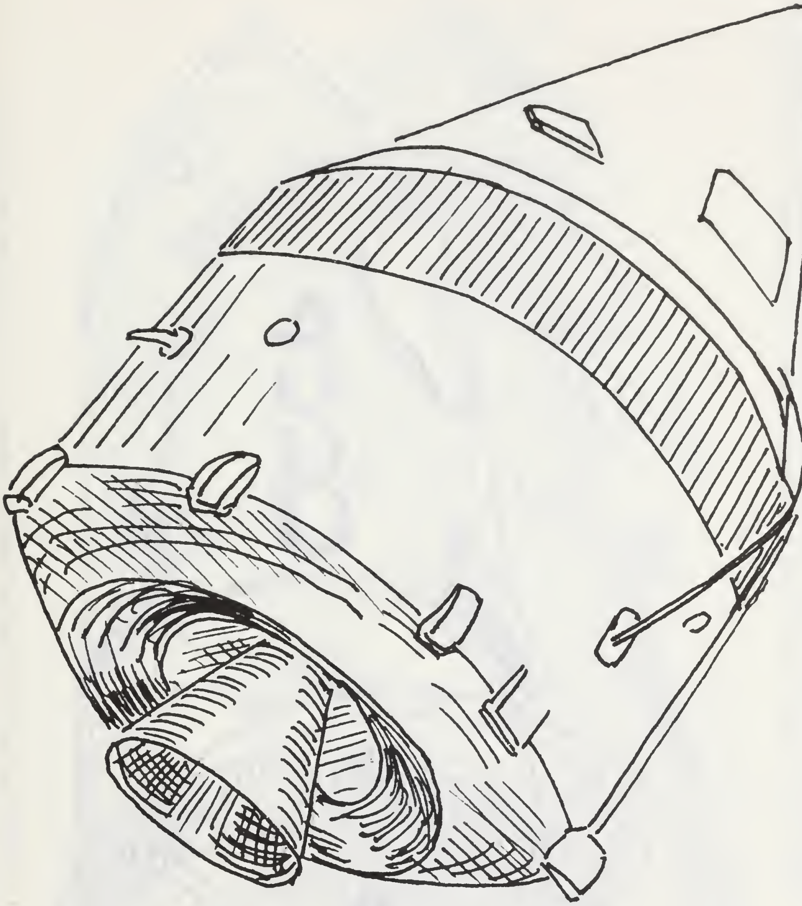

FIGURE 8.—Soviet Cosmic Rocket 1 lunar stage and nose cone containing Luna 1, to be launched by the A–1.

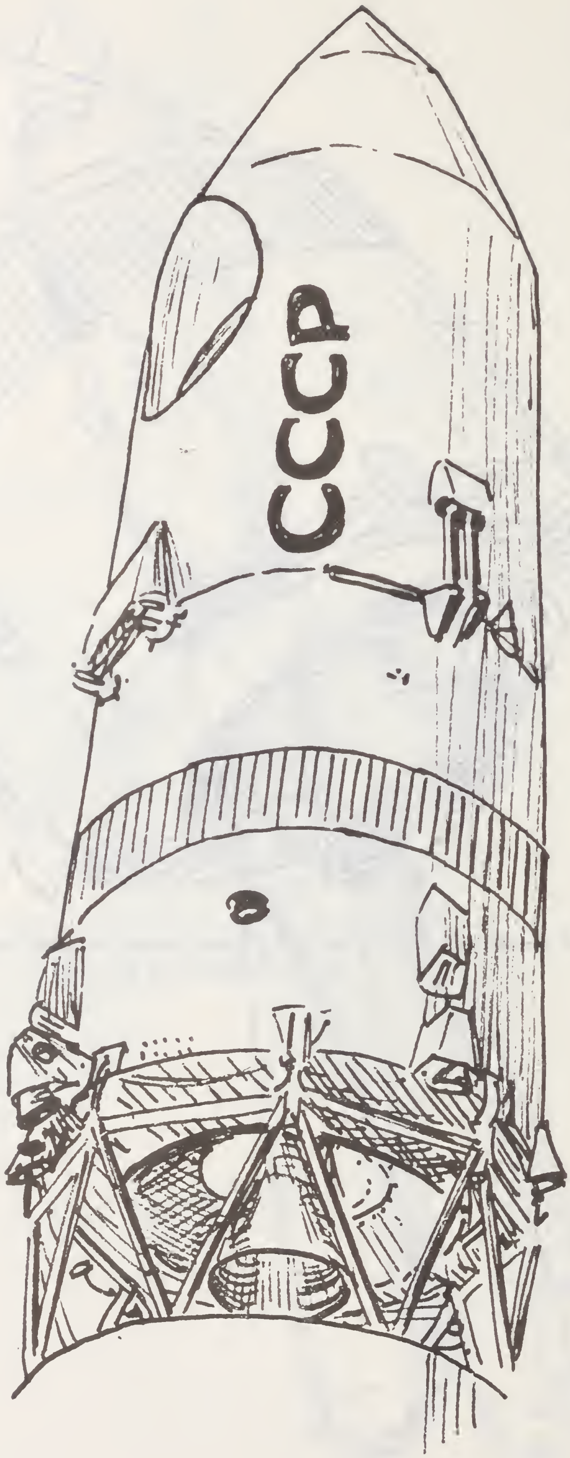

FIGURE 9.—The lunar stage with a Vostok in shroud as used for Earth orbital launches, to be launched by the A-1.

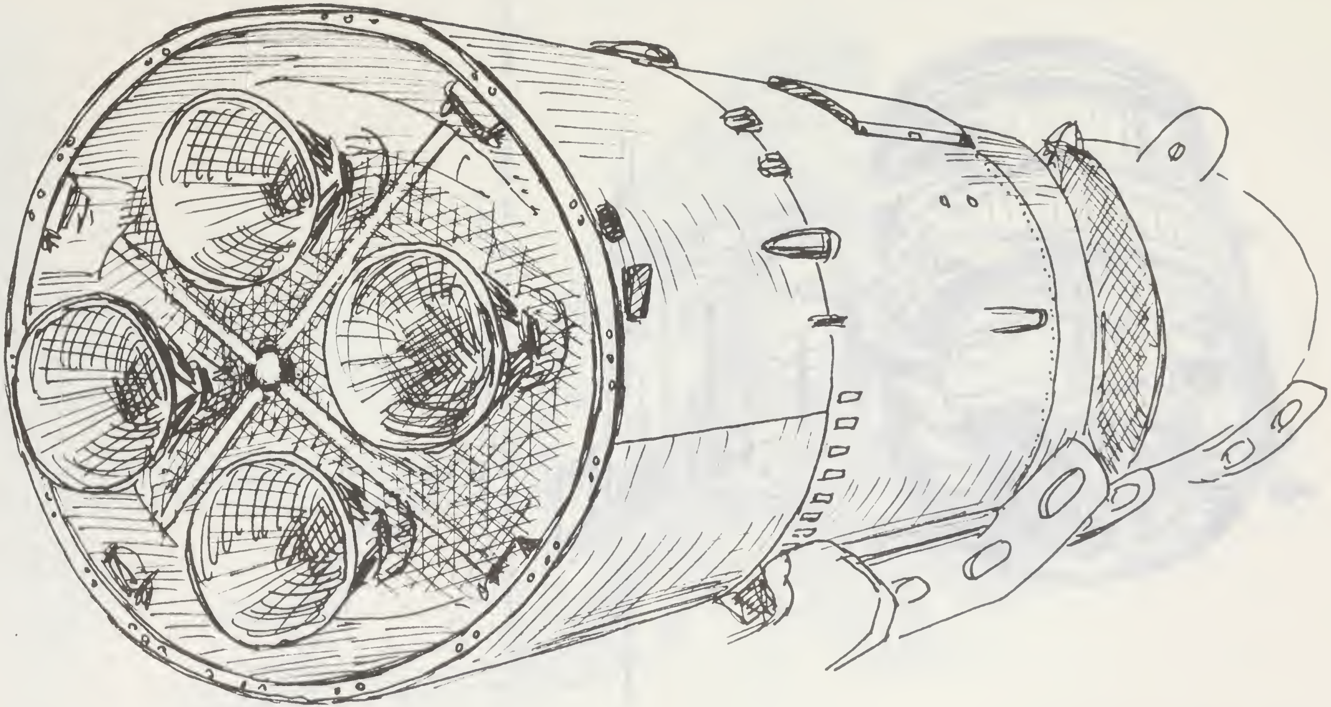

FIGURE 10.—The interplanetary stage, used for deep space and also for the bulk of Earth orbital missions, in the assembly building at Tyuratam. This rocket, used for the A–2, has a longer tank, and four nozzles instead of one, in contrast with the lunar stage used for the A–1.

FIGURE 11.—The escape stage used on the A-2-e in the assembly building at Tyuratam. (Drawing by C. P. Vick.)

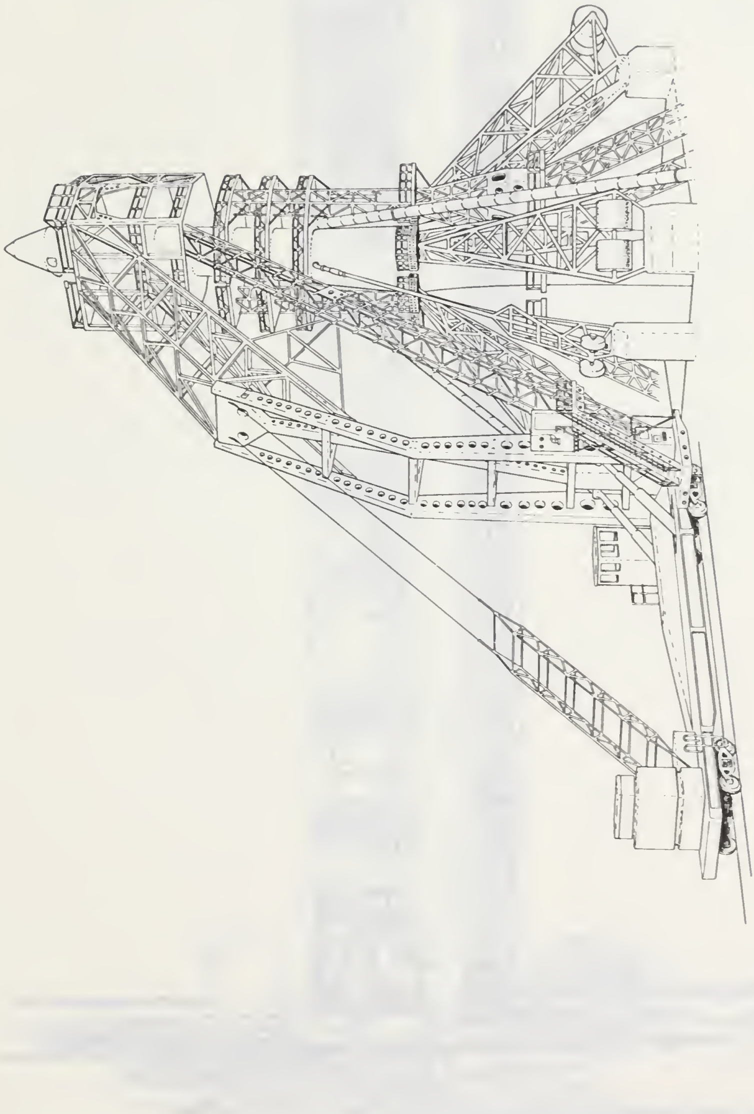

FIGURE 12.—Soviet A–1 or A–2 launch vehicle on the pad at Tyuratam. (Copyrighted drawing by D. R. Woods.)

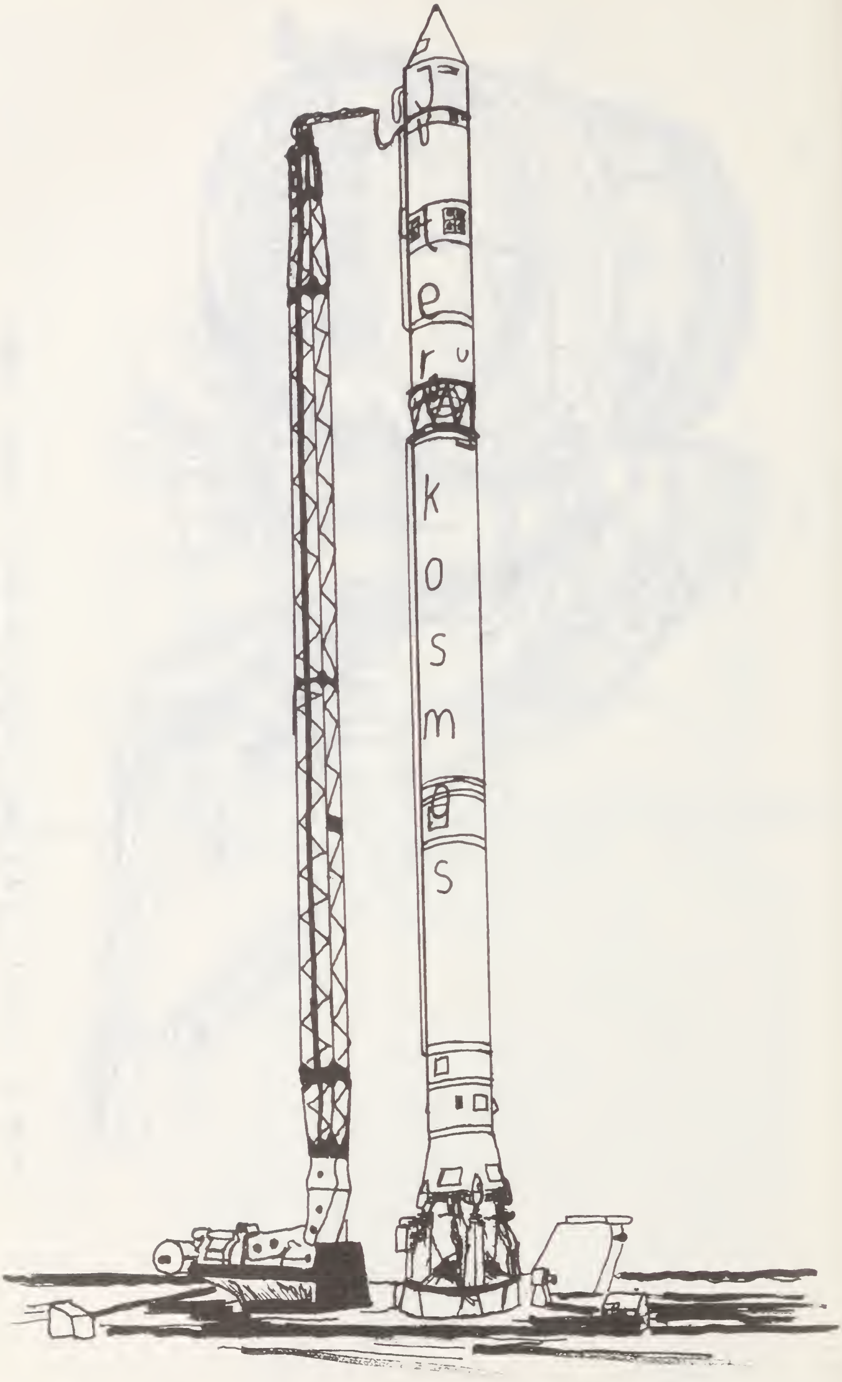

FIGURE 13.—Soviet B–1 launch vehicle on the pad. (Drawing by C. P. Vick.)

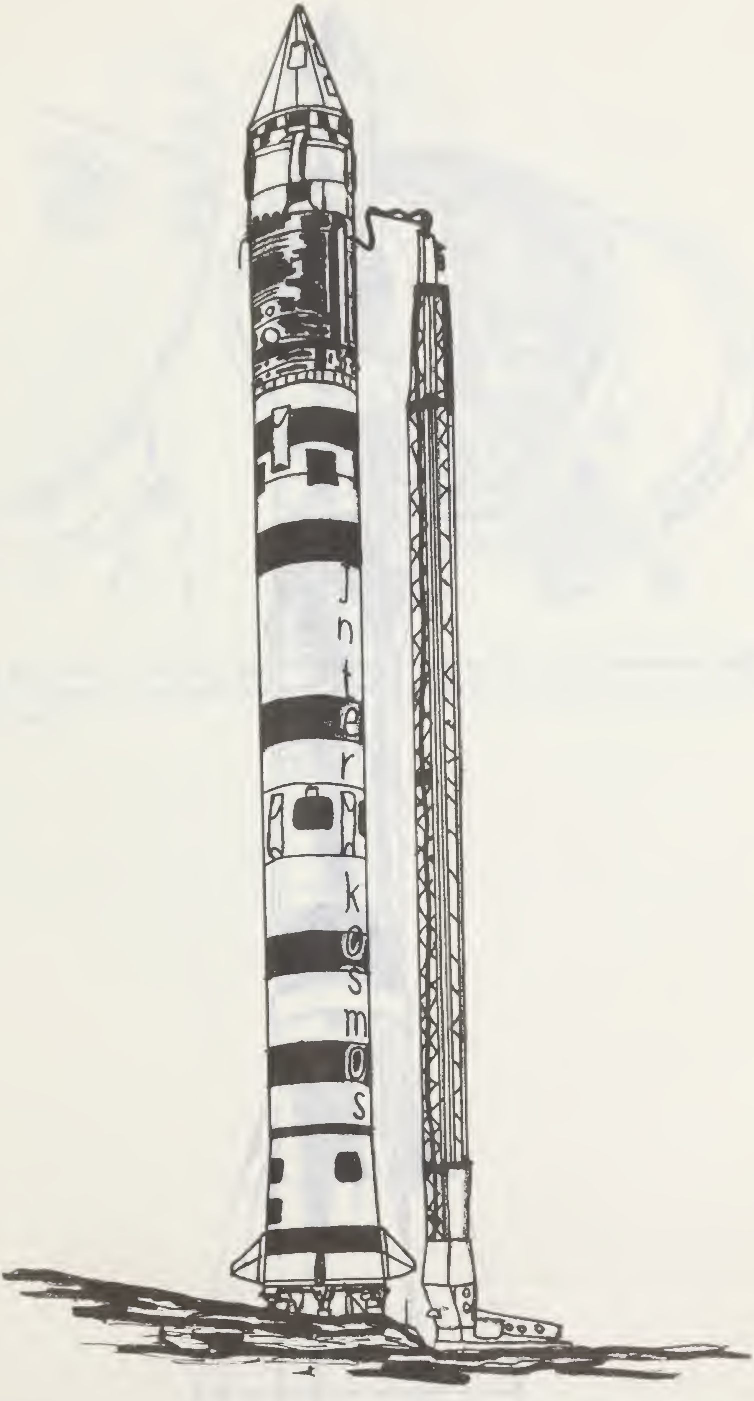

FIGURE 14.—Soviet C–1 launch vehicle on the pad. (Drawing by C. P. Vick.)

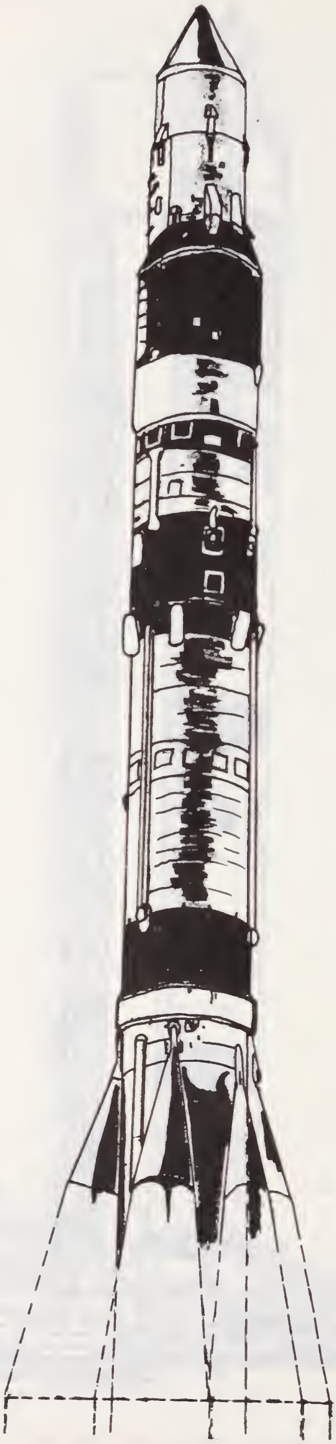

FIGURE 15.—Soviet D–1 launch vehicle upper portion from a film clip. (Drawing by C. P. Vick.)

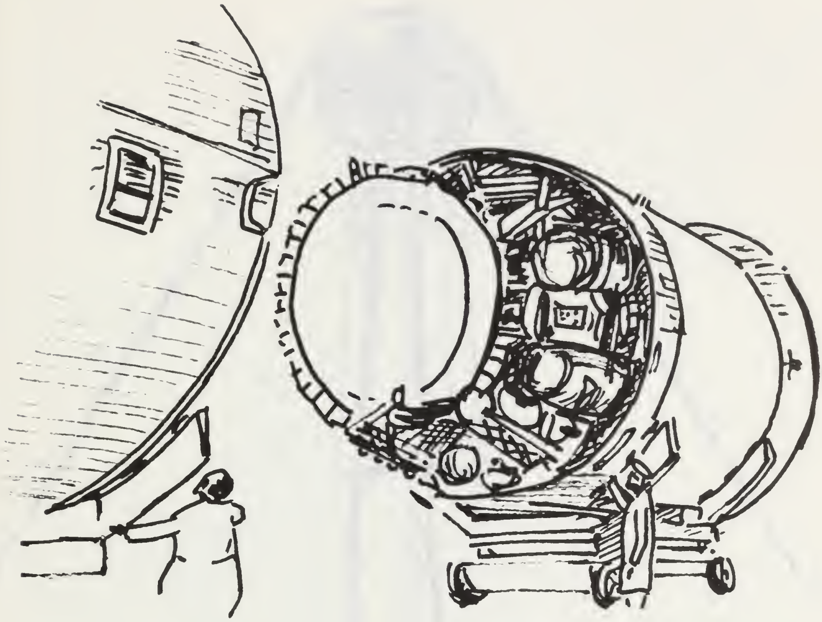

FIGURE 16.—The escape portion of a D–1–e launch vehicle in the assembly building in Tyuratam, carrying Luna 17 and Lunokhod 1 about to be mated with its shroud.

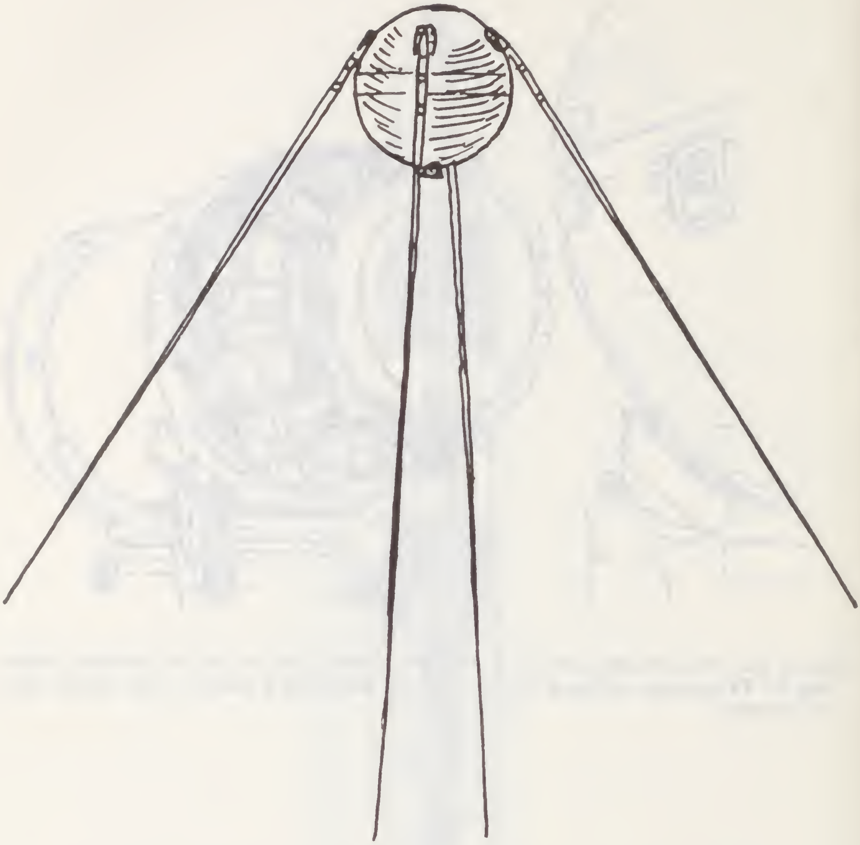

FIGURE 17.—Sputnik 1, the world's first artificial Earth satellite.

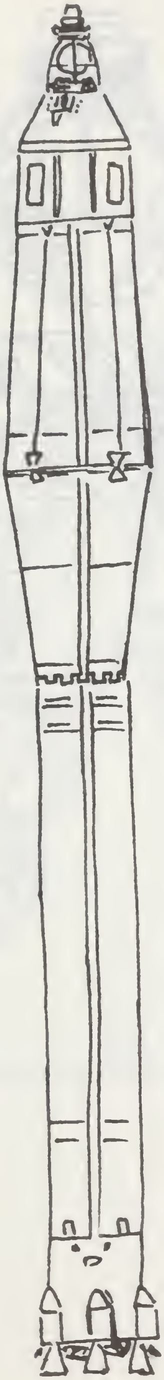

FIGURE 18.—Sputnik 2, consisting of the core portion of the A launch vehicle plus the payload itself.

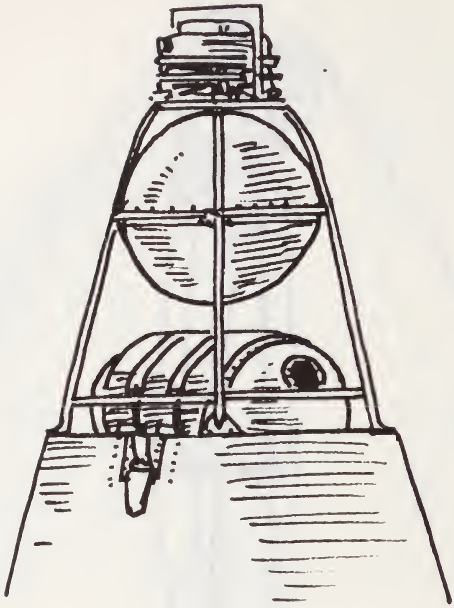

FIGURE 19.—Payload portion of Sputnik 2. The barrel-shaped object was the container for the dog Layka.

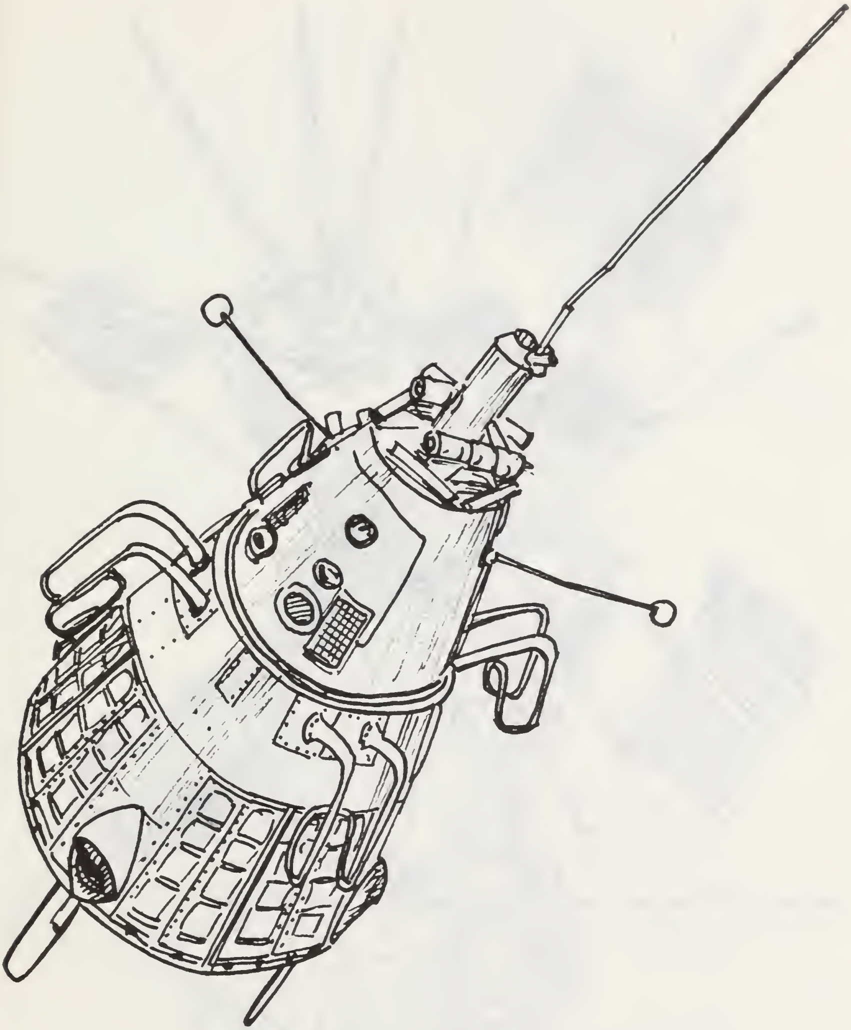

FIGURE 20.—Sputnik 3, the long-life orbiting geophysical observatory.

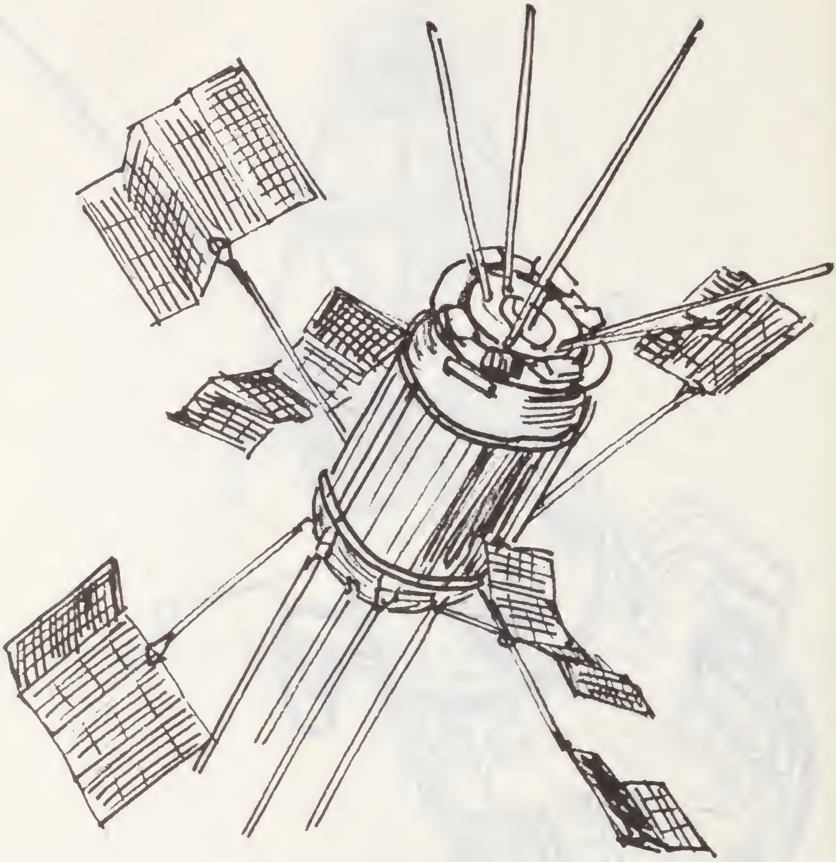

FIGURE 21.—Elektron 1 or 3, dual geophysical observatories.

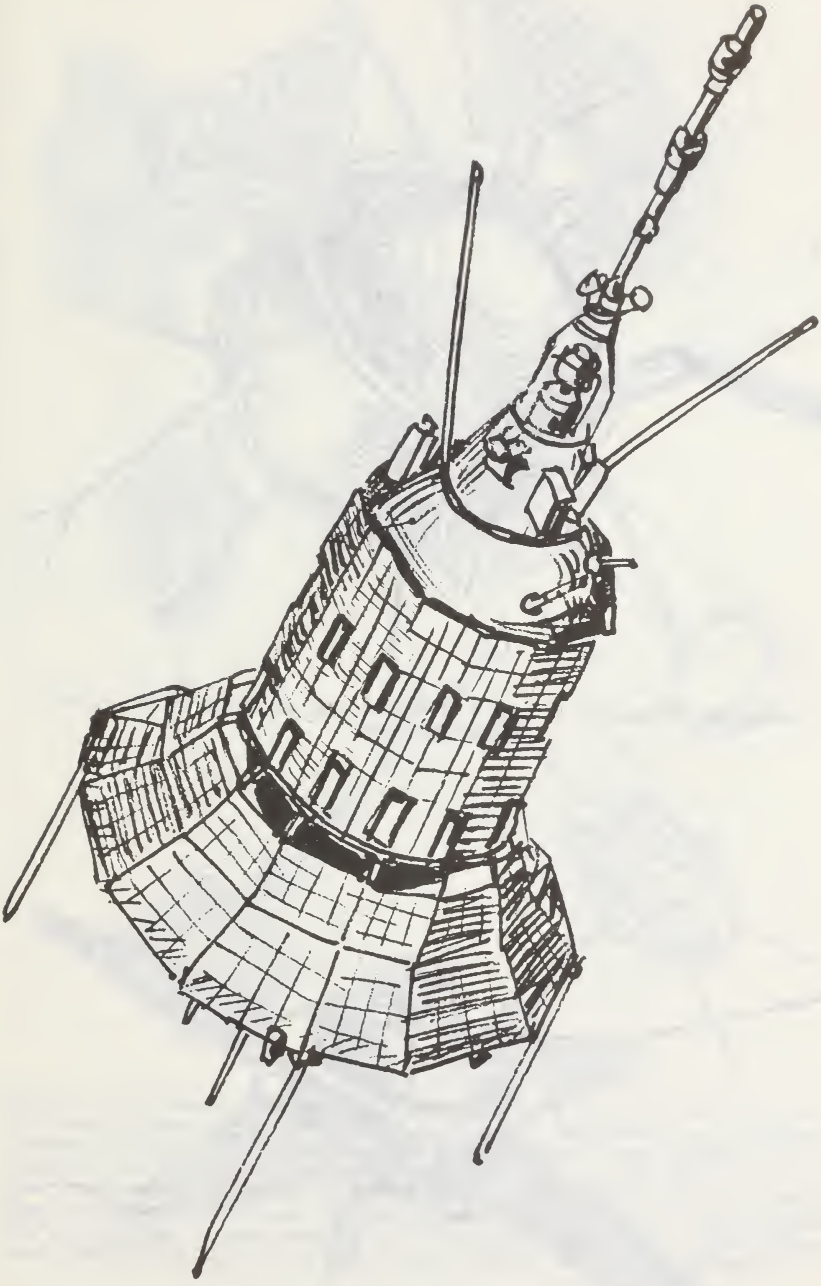

FIGURE 22.—Elektron 2 or 4, the other halves of dual geophysical observatories.

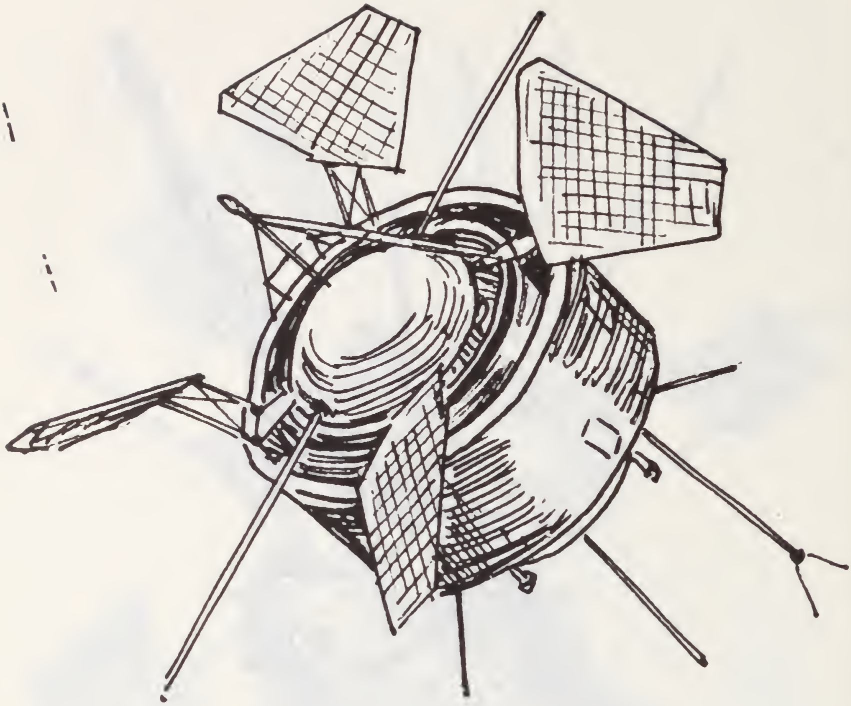

FIGURE 24.—Prognoz 1, 2, 3, or 4, to make solar wind and radiation belt measurements.

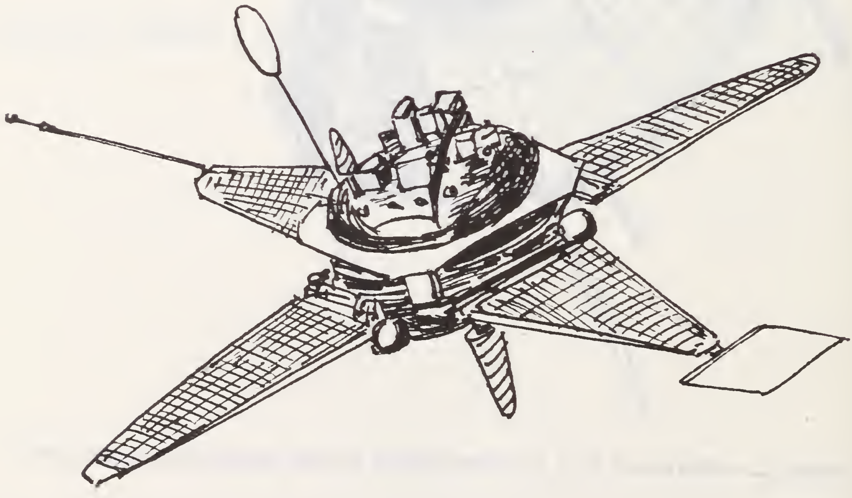

FIGURE 23.—Proton 1, 2, or 3, 12.2-metric ton stations to measure high energy particles.

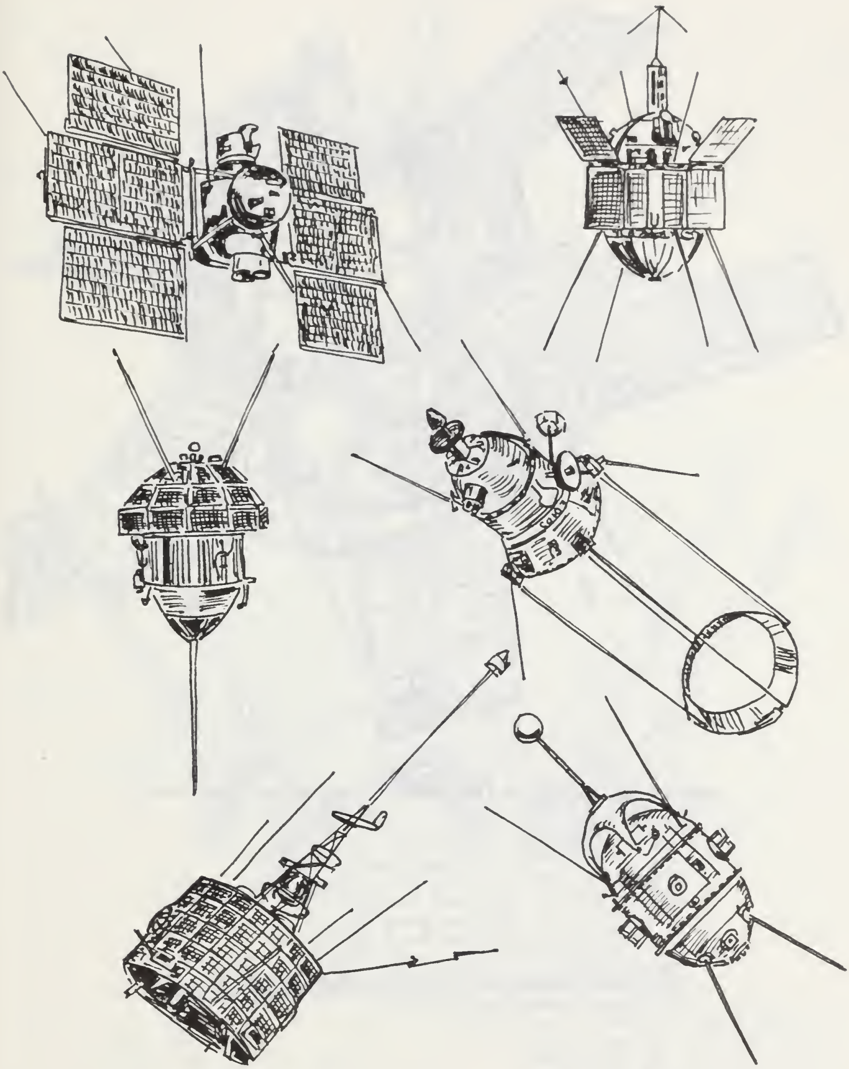

FIGURE 25.—An assortment of scientific Earth orbiting payloads. Left side, top to bottom: Kosmos 23, Kosmos 5, and Kosmos 381. Right side, top to bottom: Kosmos 97, Kosmos 149, and Kosmos 49. Kosmos 23 did meteorological work; Kosmos 5 did particle and radiation measurements; Kosmos 381 was a topside ionospheric sounder; Kosmos 97 carried a maser and atomic clock; Kosmos 149 not only took cloud cover pictures but after attaining orbit deployed the annular ring on long rods as an orientation means in the upper atmosphere; Kosmos 49 made studies of magnetic fields, IR and UV radiation.

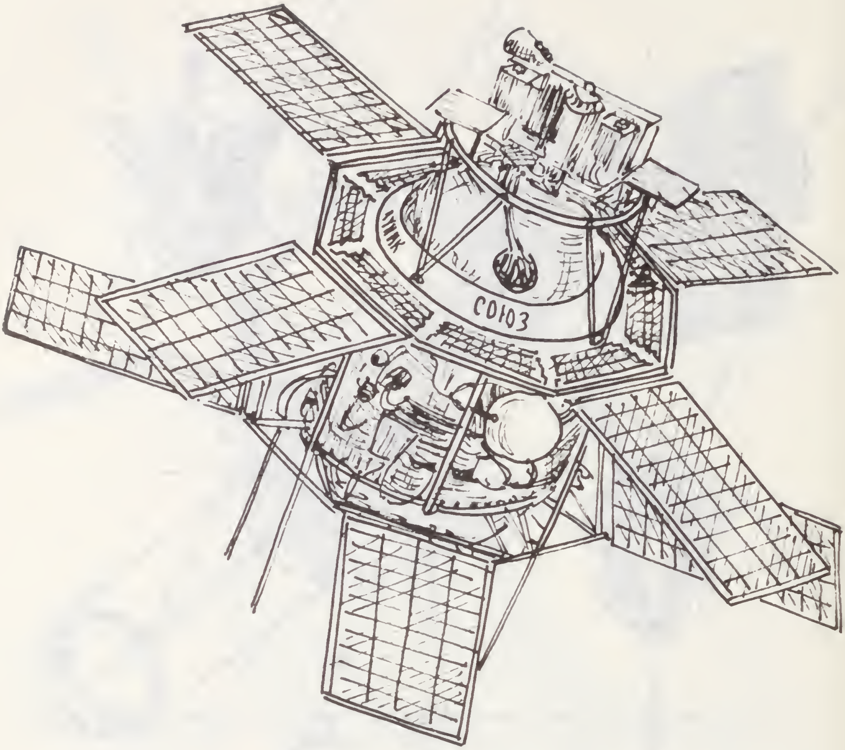

Figure 26.—Kosmos 166, an orbiting solar observatory.

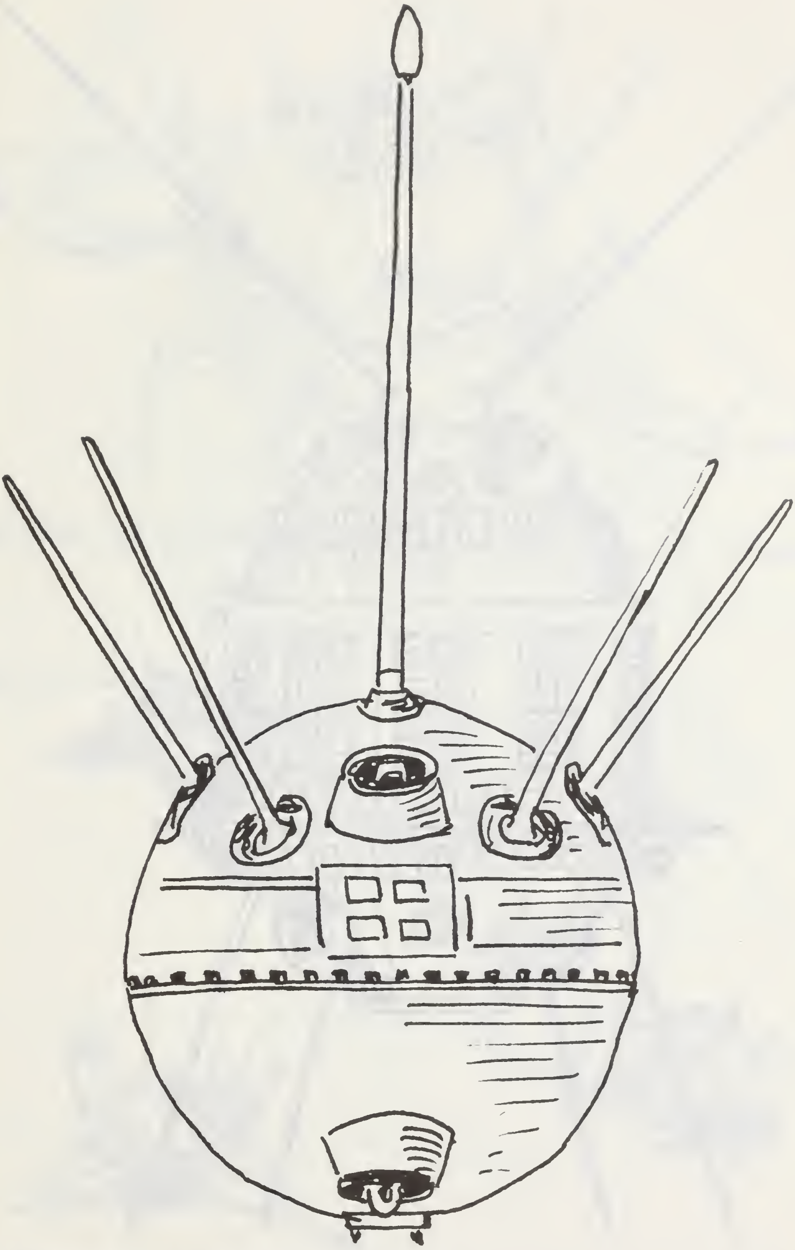

FIGURE 27.—Luna 1 or 2 after separation from Cosmic Rocket 1 or 2.

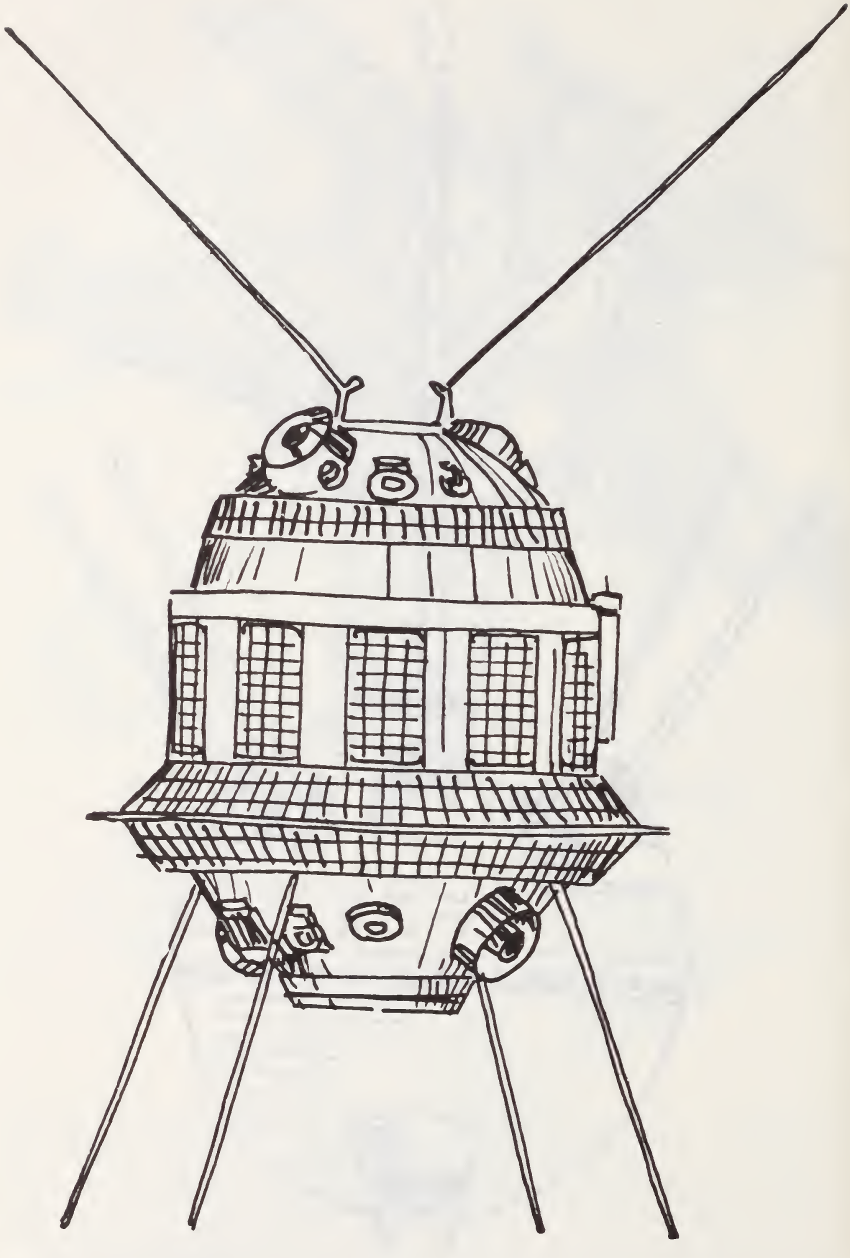

FIGURE 28.—Luna 3 Automatic Interplanetary Station for taking pictures of the far side of the Moon.

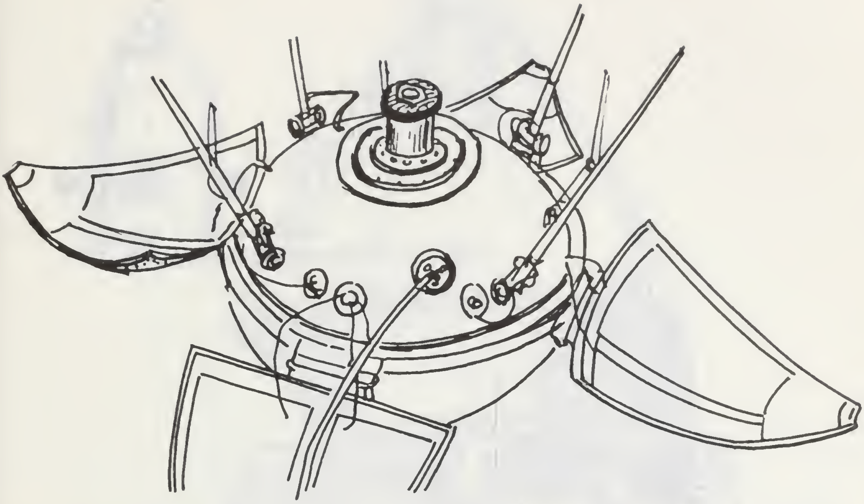

FIGURE 29.—Luna 9 details, in open position for taking pictures on the surface of the Moon.

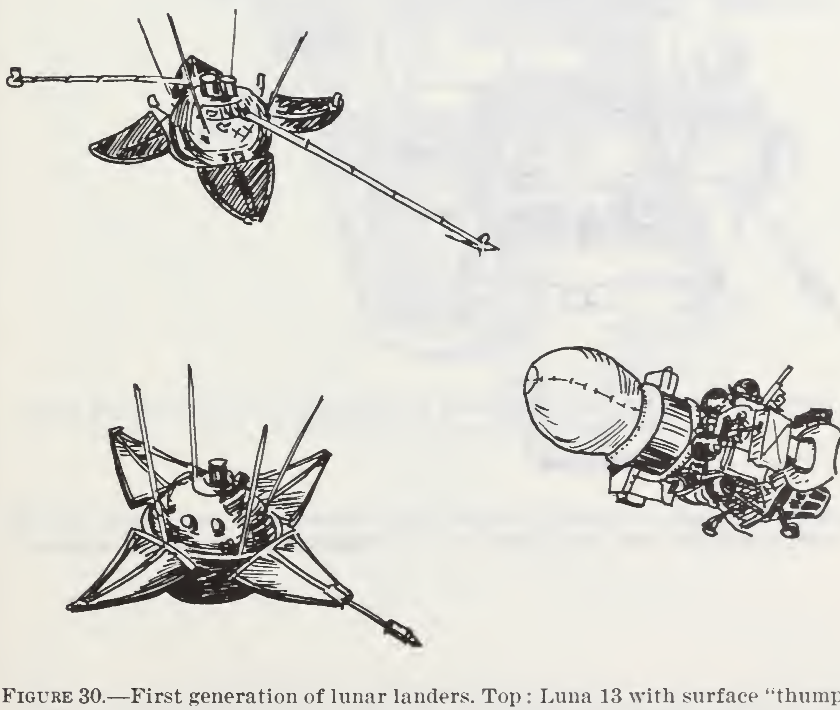

FIGURE 30.—First generation of lunar landers. Top: Luna 13 with surface "thumpers" to test soil. Lower left: Luna 9, the first successful lander. Lower right: The flight configuration of the landers on the way to the Moon with the bus and the attached lander in its protective blanket.

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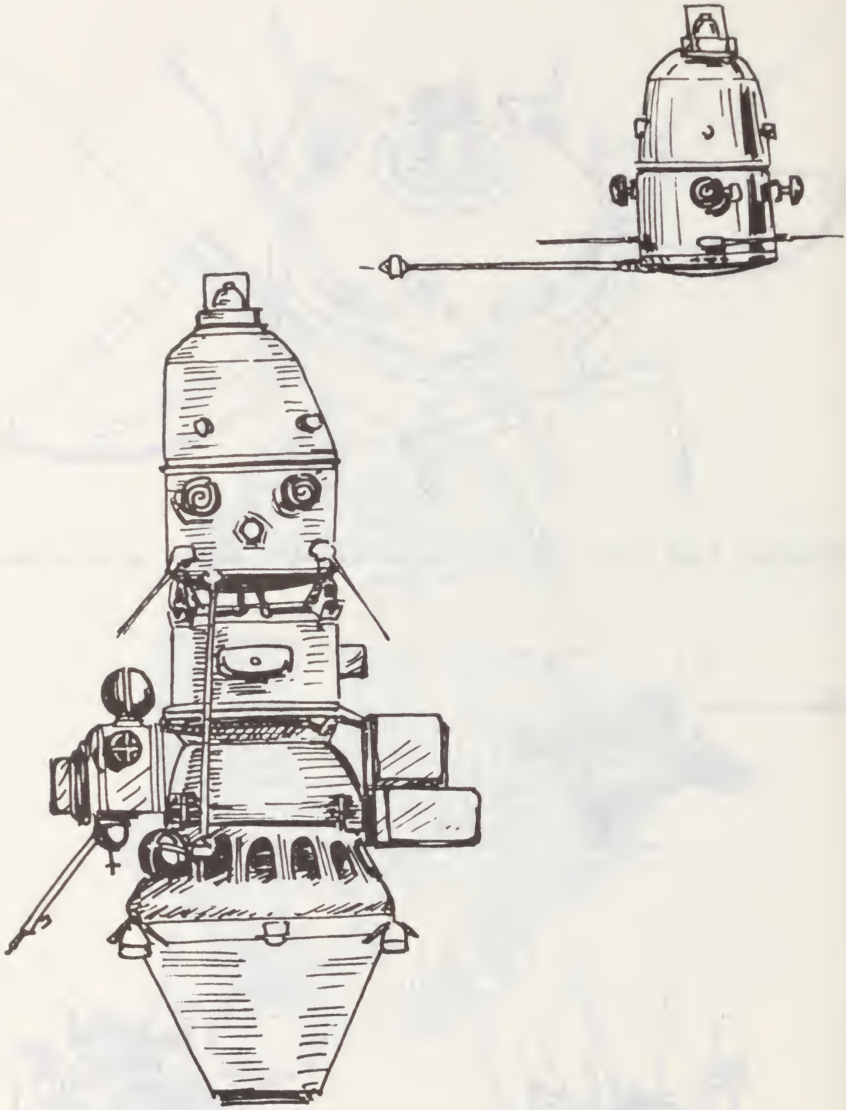

FIGURE 31.—Luna 10 showing the bus which carried it to lunar orbit, and the orbital payload both as attached and as separated for its orbital mission.

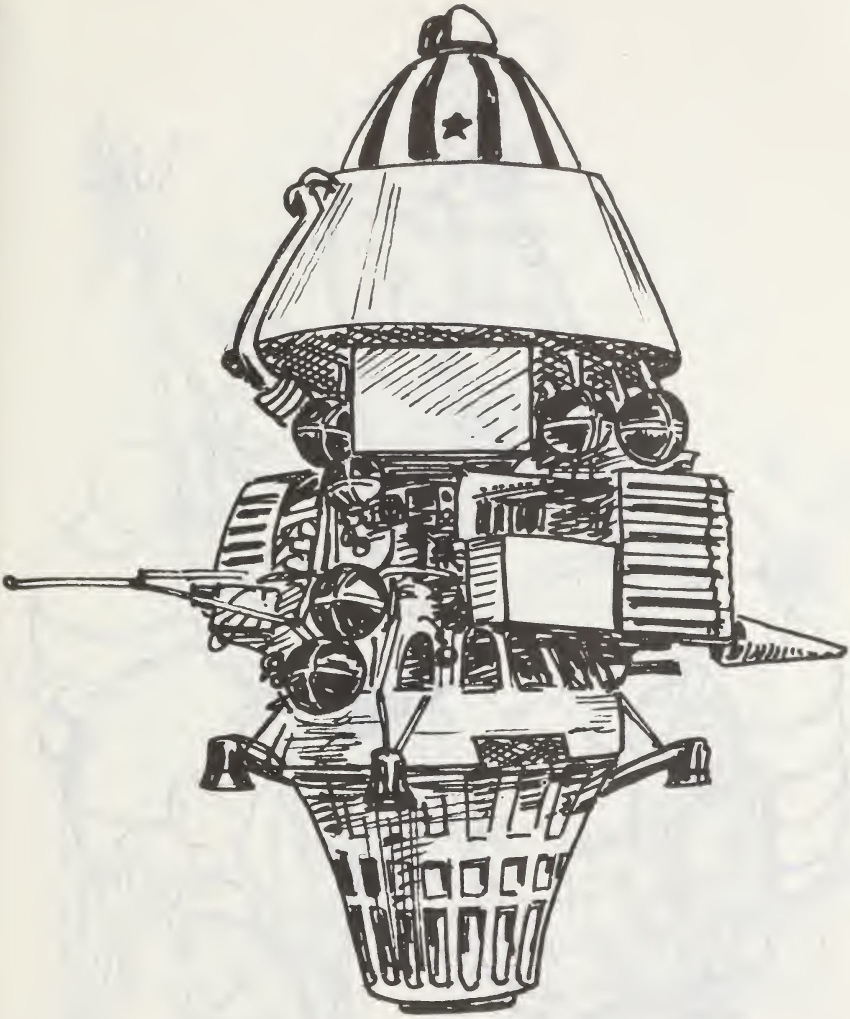

FIGURE 32.—Luna 12, an improved first generation lunar orbiter before separation of the orbital picture-taking payload.

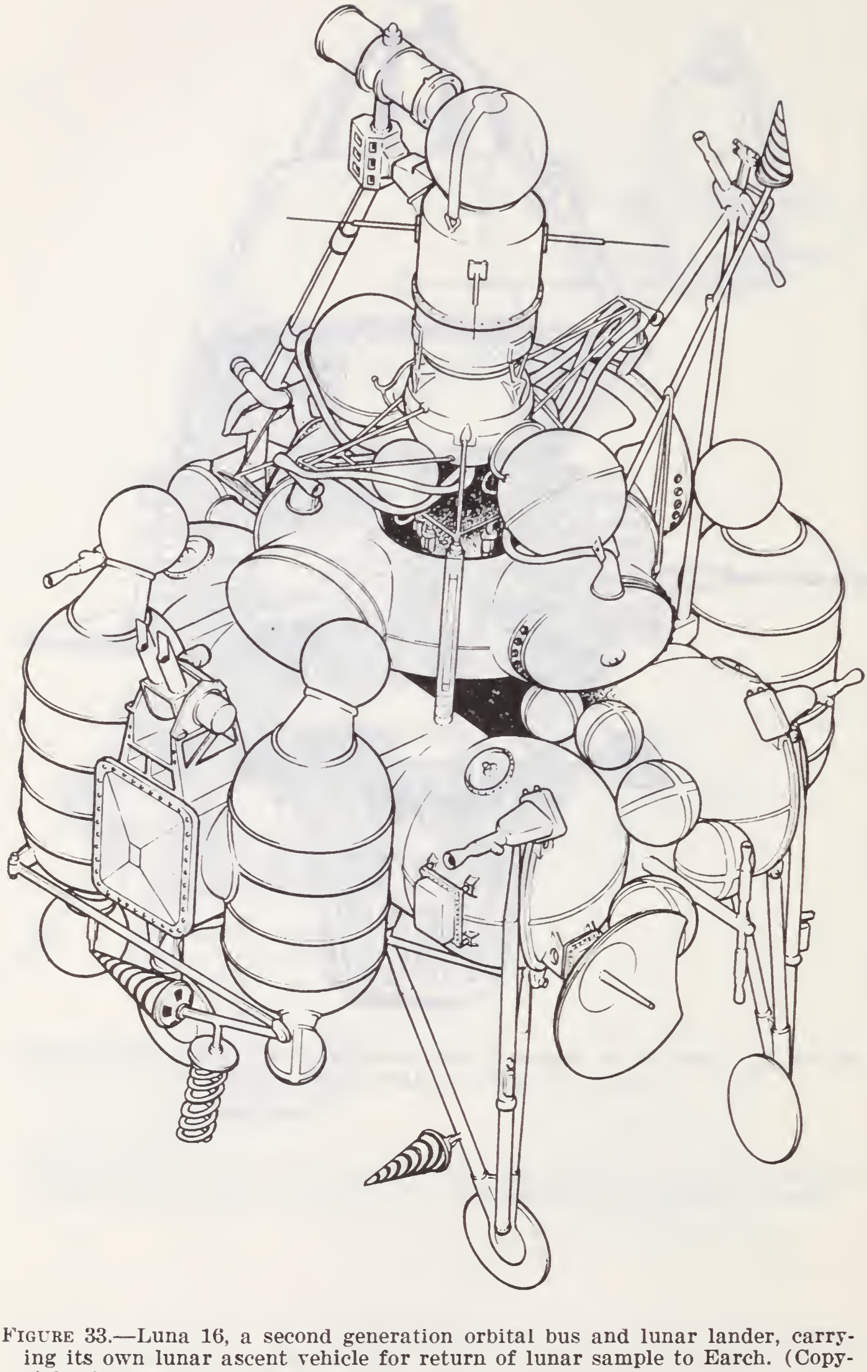

FIGURE 33.—Luna 16, a second generation orbital bus and lunar lander, carrying its own lunar ascent vehicle for return of lunar sample to Earch. (Copyrighted drawing by D. R. Woods.)

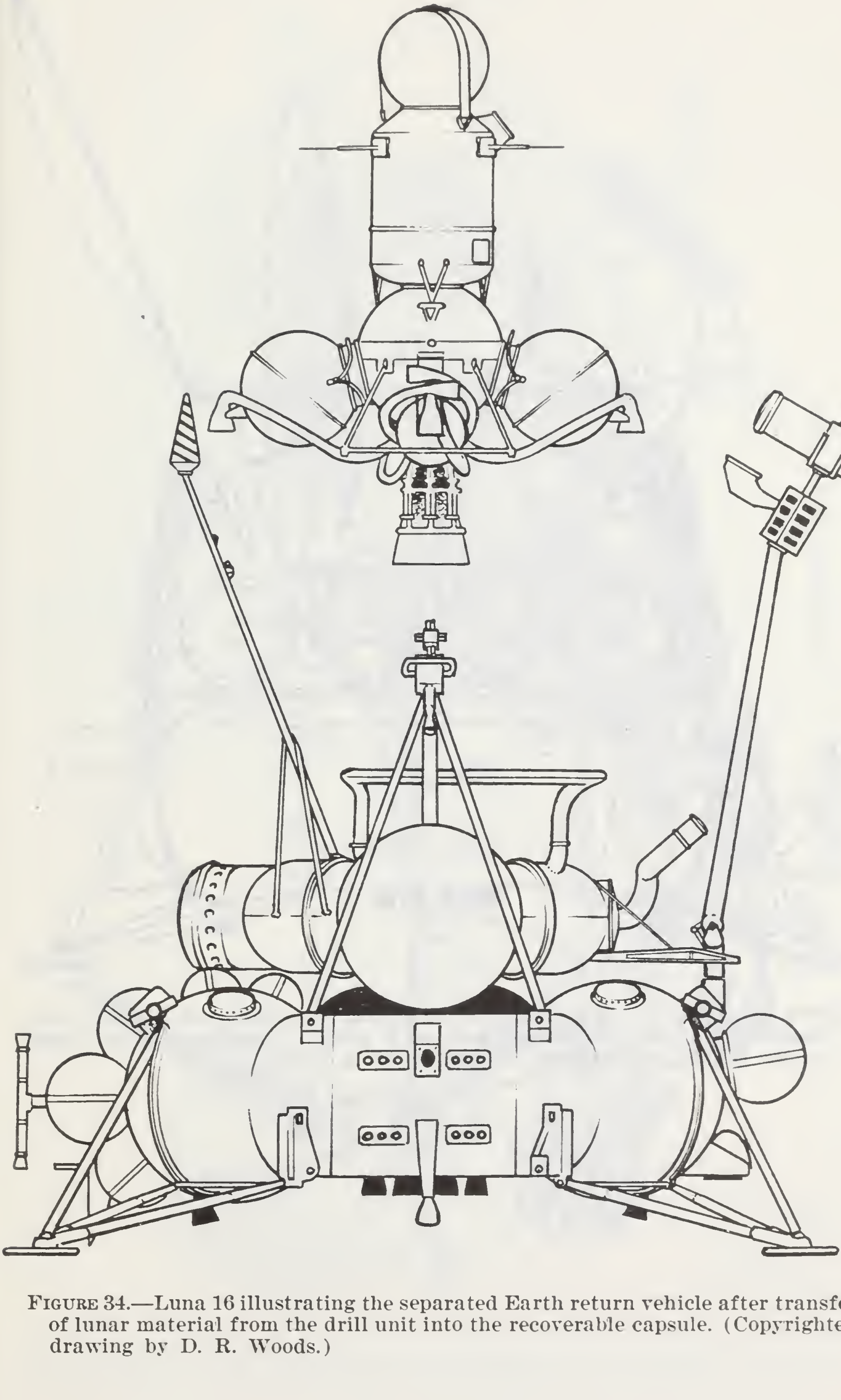

Figure 34.—Luna 16 illustrating the separated Earth return vehicle after transfer of lunar material from the drill unit into the recoverable capsule. (Copyrighted drawing by D. R. Woods.)

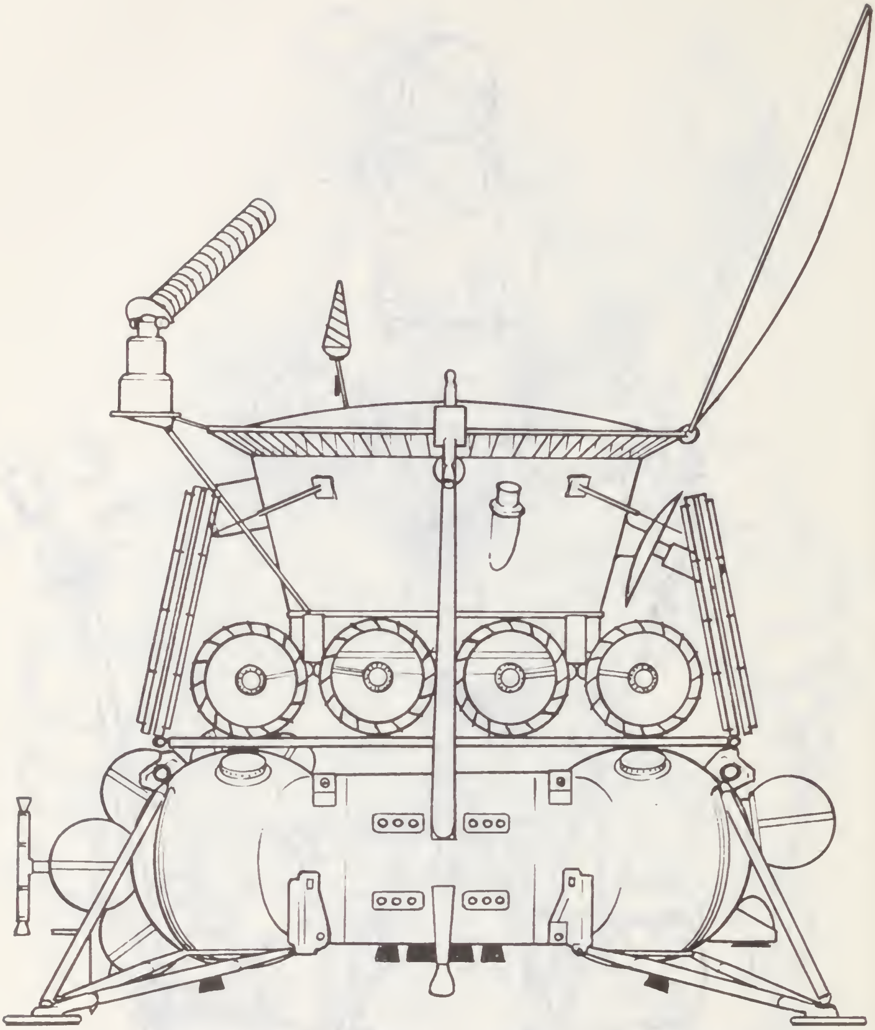

FIGURE 35.—Luna 17, using the second generation lunar orbiter and lander, with Lunokhod 1 roving vehicle mounted on it before deployment of the folded landing ramps. (Copyrighted drawing by D. R. Woods.)

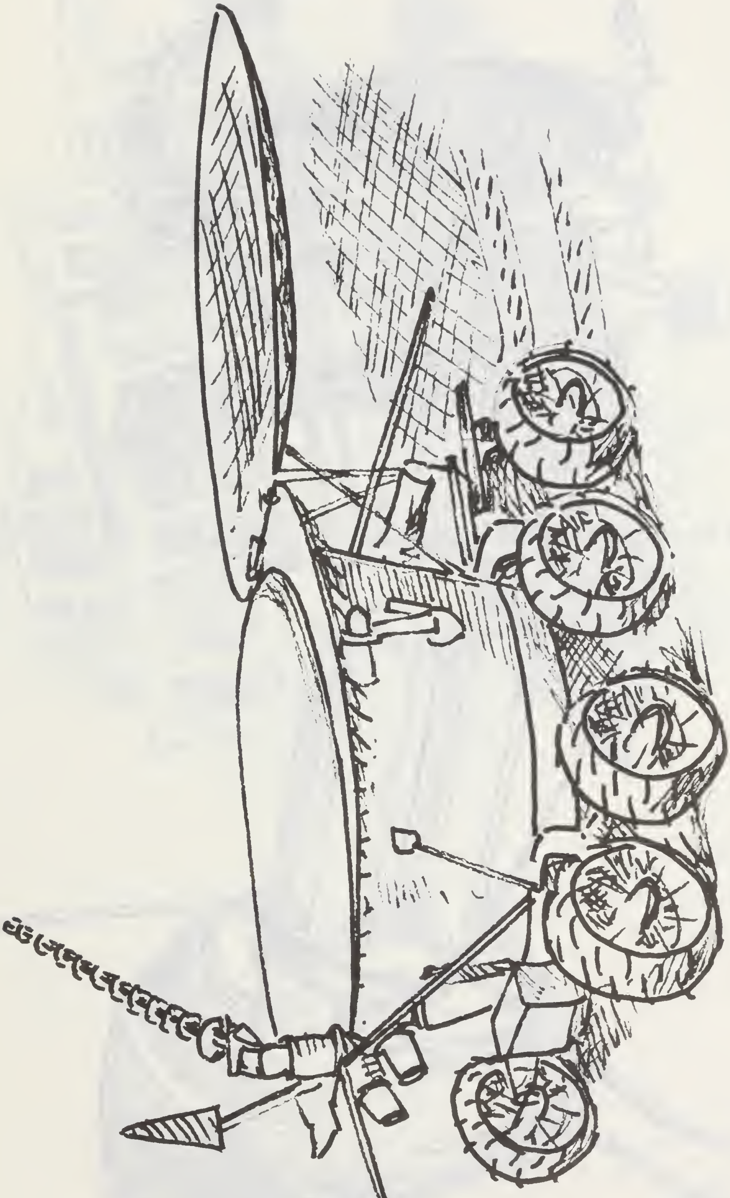

FIGURE 36.—Lunokhod 1 on the surface of the Moon.

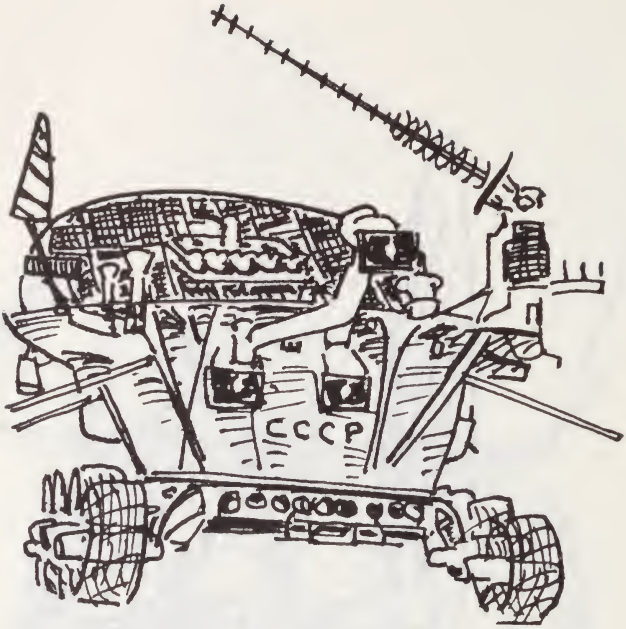

FIGURE 37.—Lunokhod 2, the heavier improved roving vehicle with extra, higher-placed television camera.

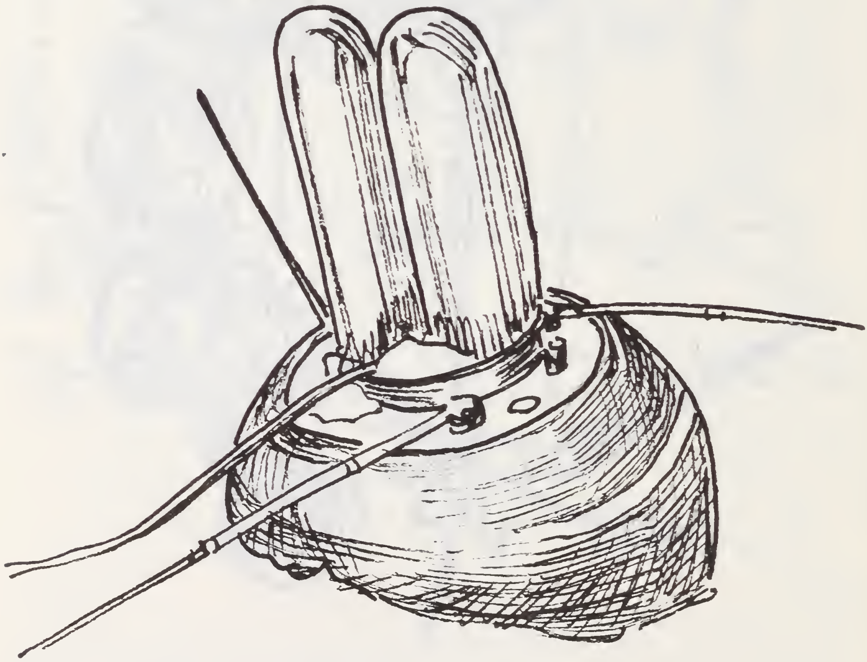

FIGURE 38.—The return capsule of Luna 20 as found in the snow of Kazakhstan, with inflated flotation units extended, radio antennas, and parachute shrouds.

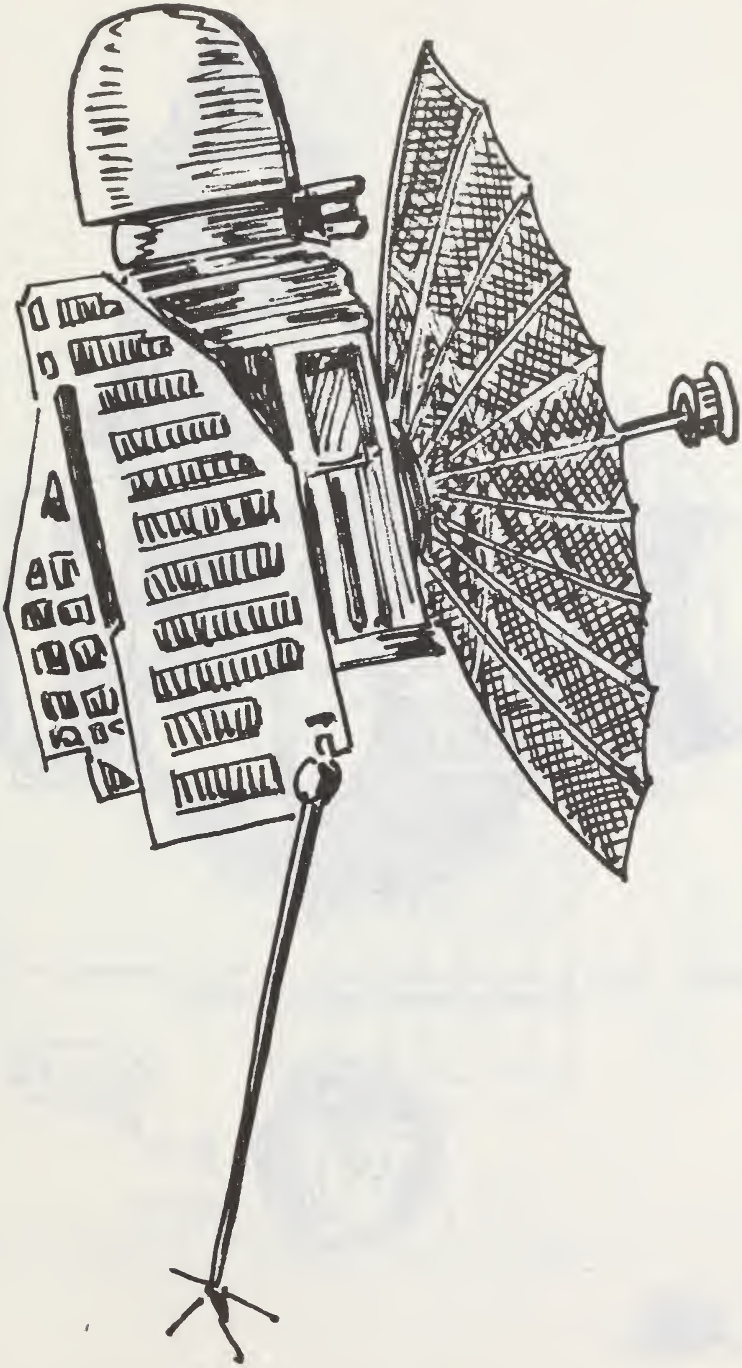

FIGURE 39.—Venera 1, the first payload sent to Venus.

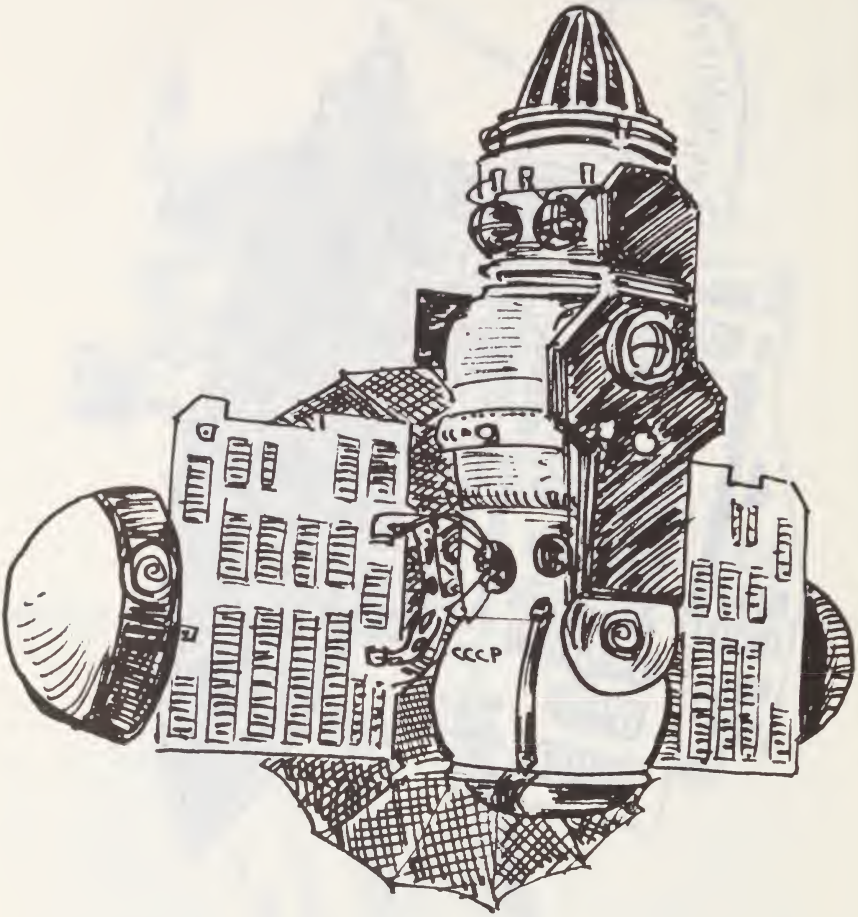

FIGURE 40.—Venera 3, essentially like Venera 4–8, with a detachable capsule intended to make a landing on Venus.

FIGURE 41.—The landed capsule from Venera 8 which operated for 50 minutes on the surface of Venus, measuring temperature, pressure, atmospheric and soil components. Nearby are both the braking parachute and a connected container used as a backup to the main instrument package.

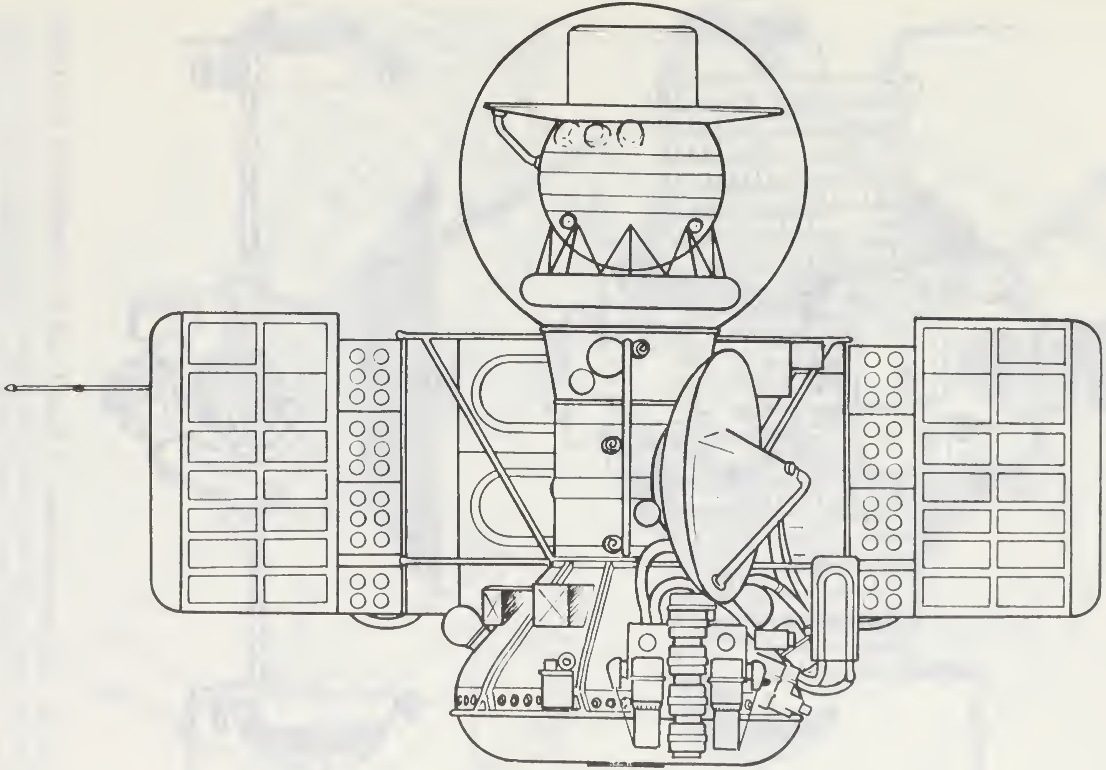

FIGURE 42.—Venera 9 or 10, second generation Venus payloads consisting both of an orbital bus and relay station, plus the large sphere showing diagrammatically the lander within, which returned in each case a panoramic view from the surface, as well as making measurements during passage through the atmosphere. (Copyrighted drawing by D. R. Woods.)

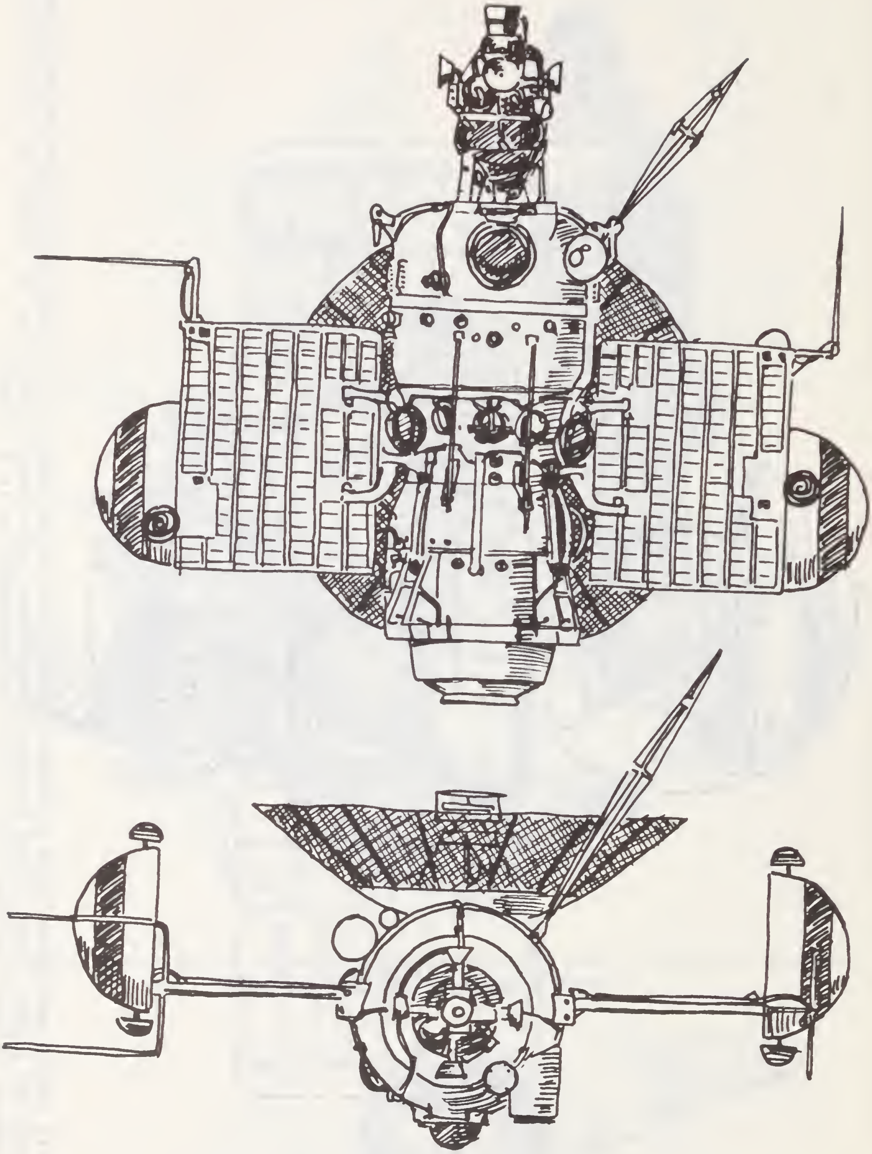

FIGURE 43.—Top and side views of Mars 1 sent to the vicinity of that planet.

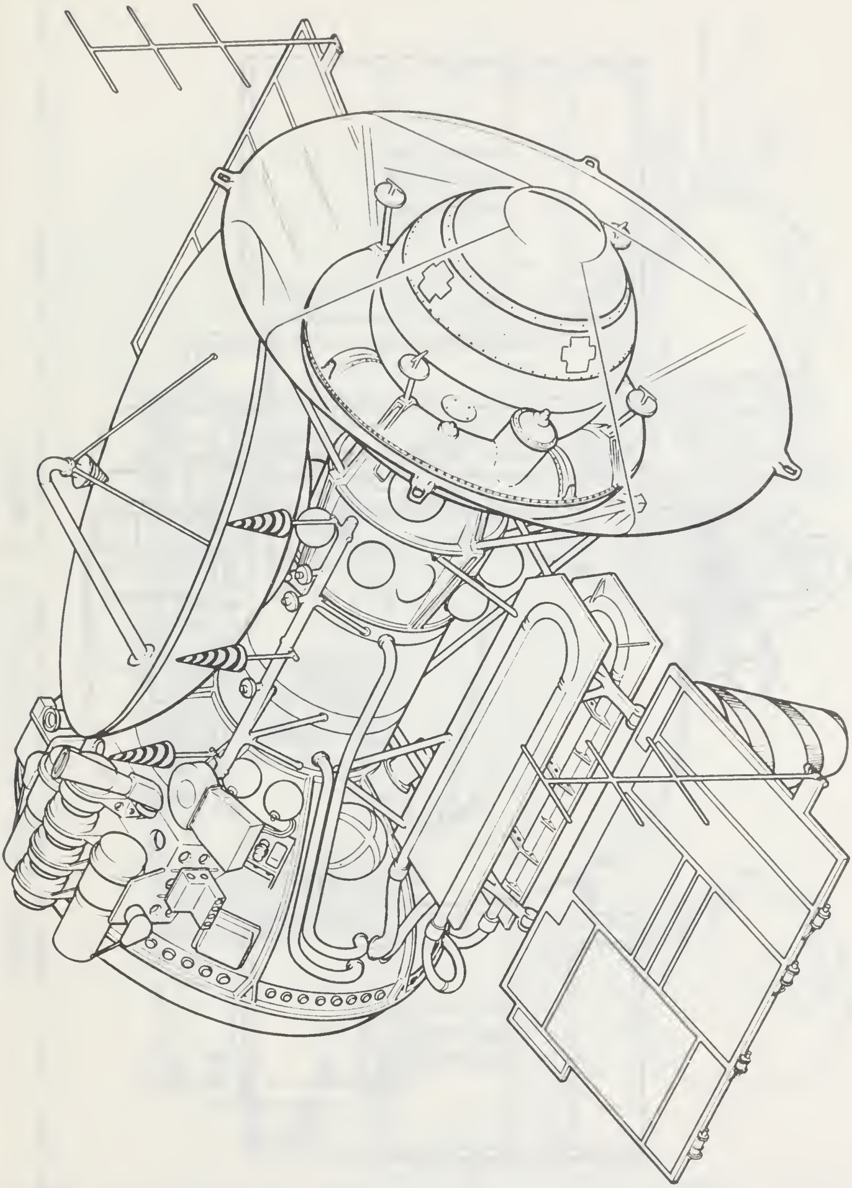

FIGURE 44.—The second generation planetary vehicles of the Mars 2 and 3 combination orbiters and landers, and Mars 6 and 7 combination fly-by and lander Mars craft. (Copyrighted drawing by D. R. Woods.)

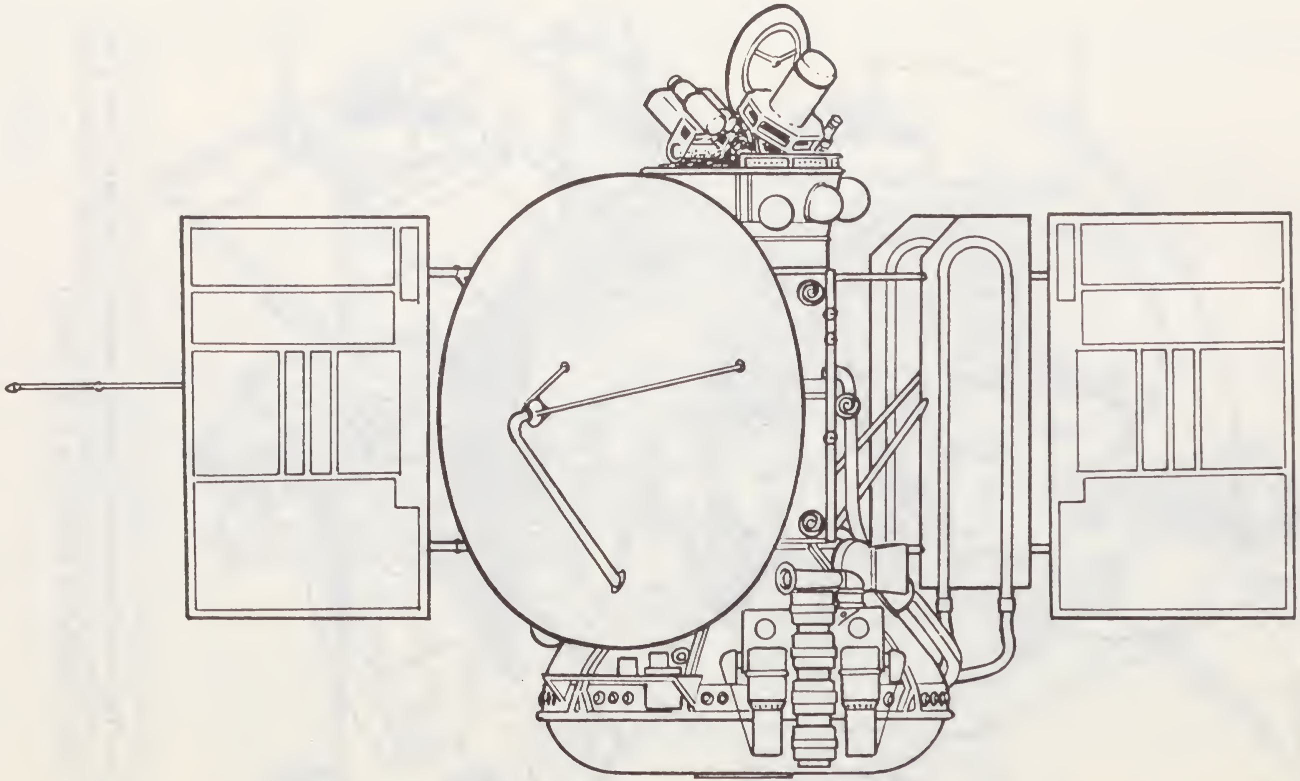

FIGURE 45.—The similar Mars 4 and 5 orbiter craft without landing capsules, also designed to serve as relays for the Mars 6 and 7 landers. (Copyrighted drawing by D. R. Woods.)

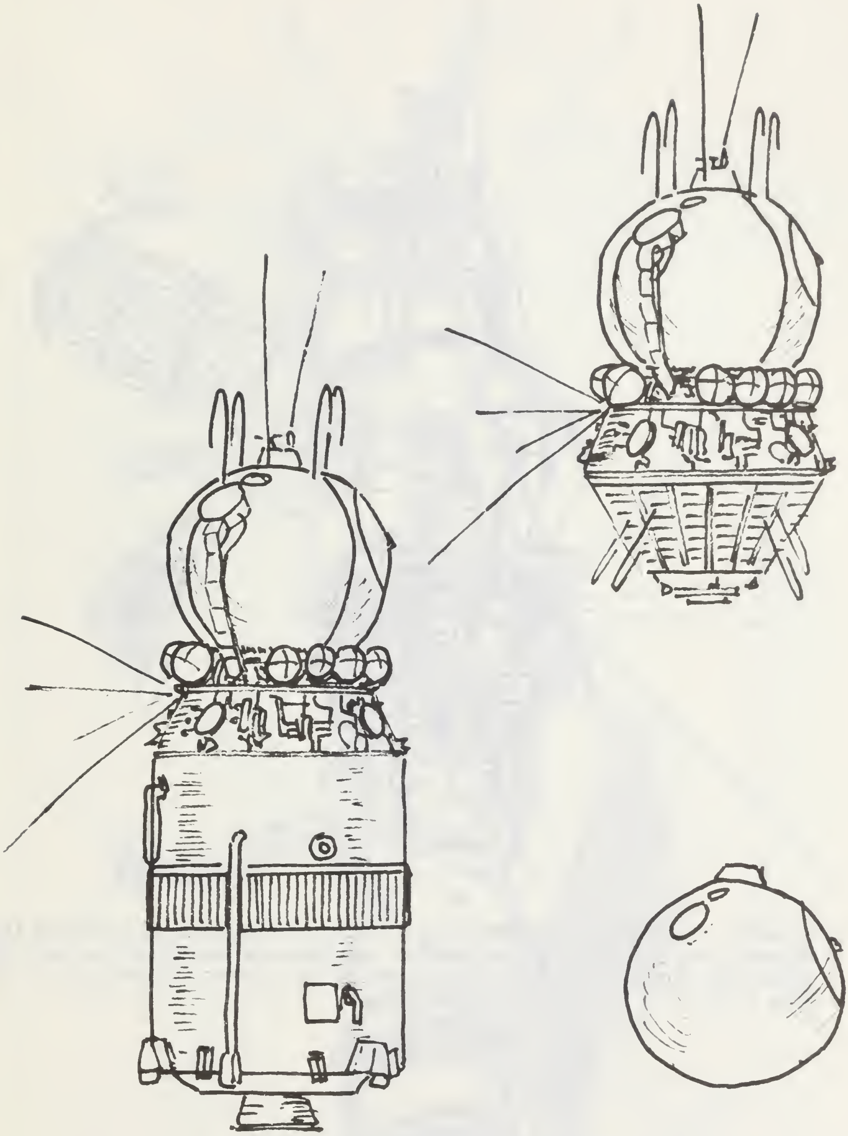

FIGURE 46.—Vostok in three guises: Left: The Vostok still attached to its lunar final stage rocket. Upper right: The Vostok in its operational form in orbit showing both the manned capsule and the service module with batteries and other support equipment. Lower right: The manned capsule as it is recovered on Earth.

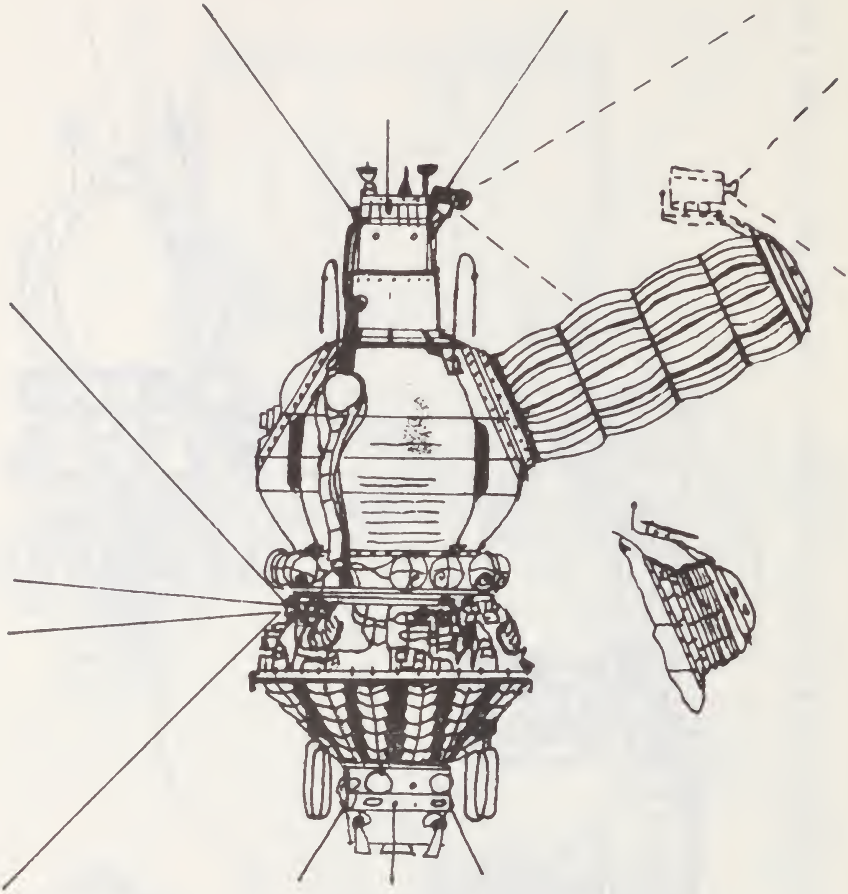

FIGURE 47.—Voskhod, a modified Vostok with extra retro-rocket at the end of the capsule away from the service module, and views of the airlock as used on Voskhod 2, both inflated and (inset) before deployment. (Drawing by C. P. Vick.)

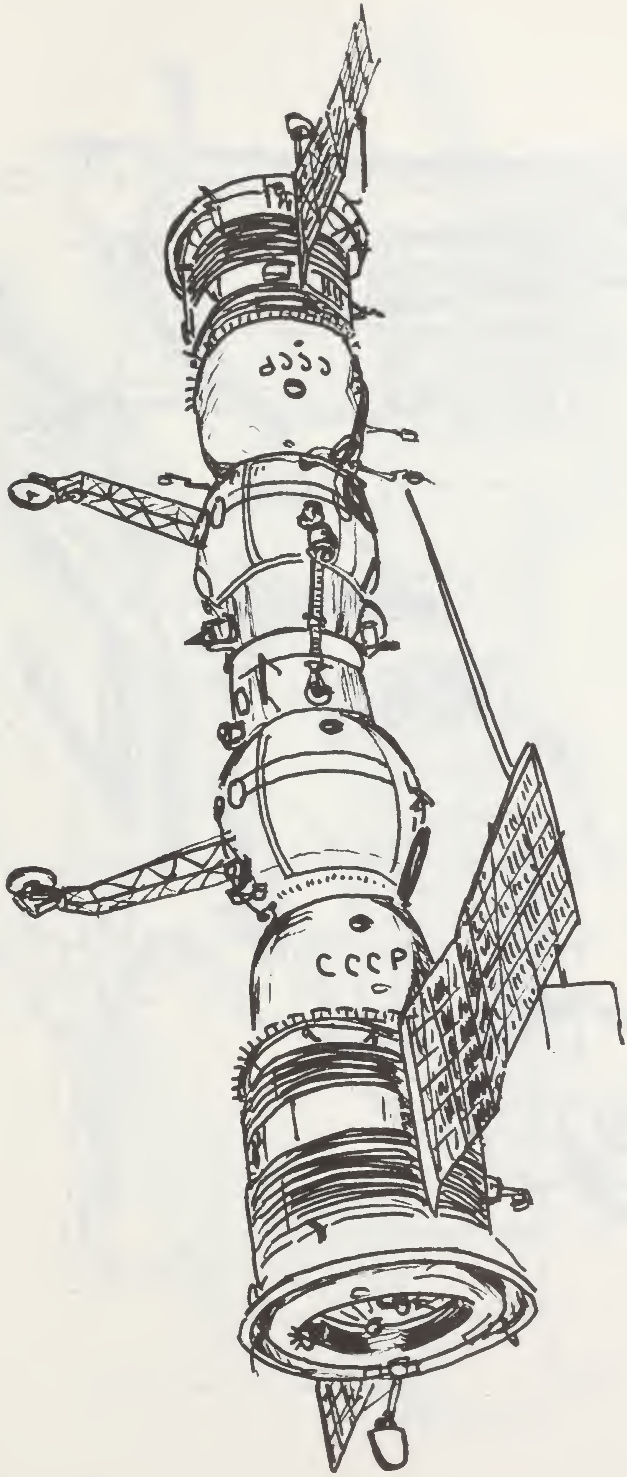

FIGURE 48.—Soyuz 4 and 5 as docked in space.

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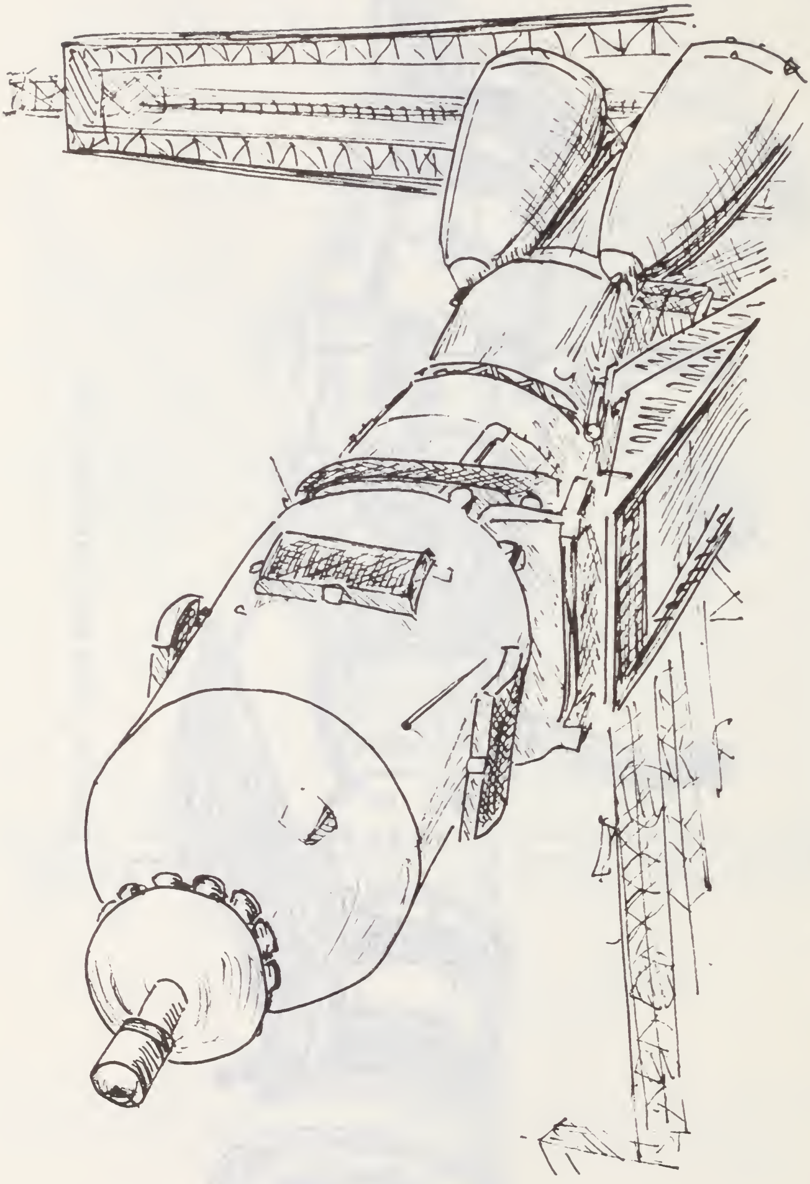

FIGURE 49.—Soyuz 9 on its transporter just before pad erection at Tyuratam.

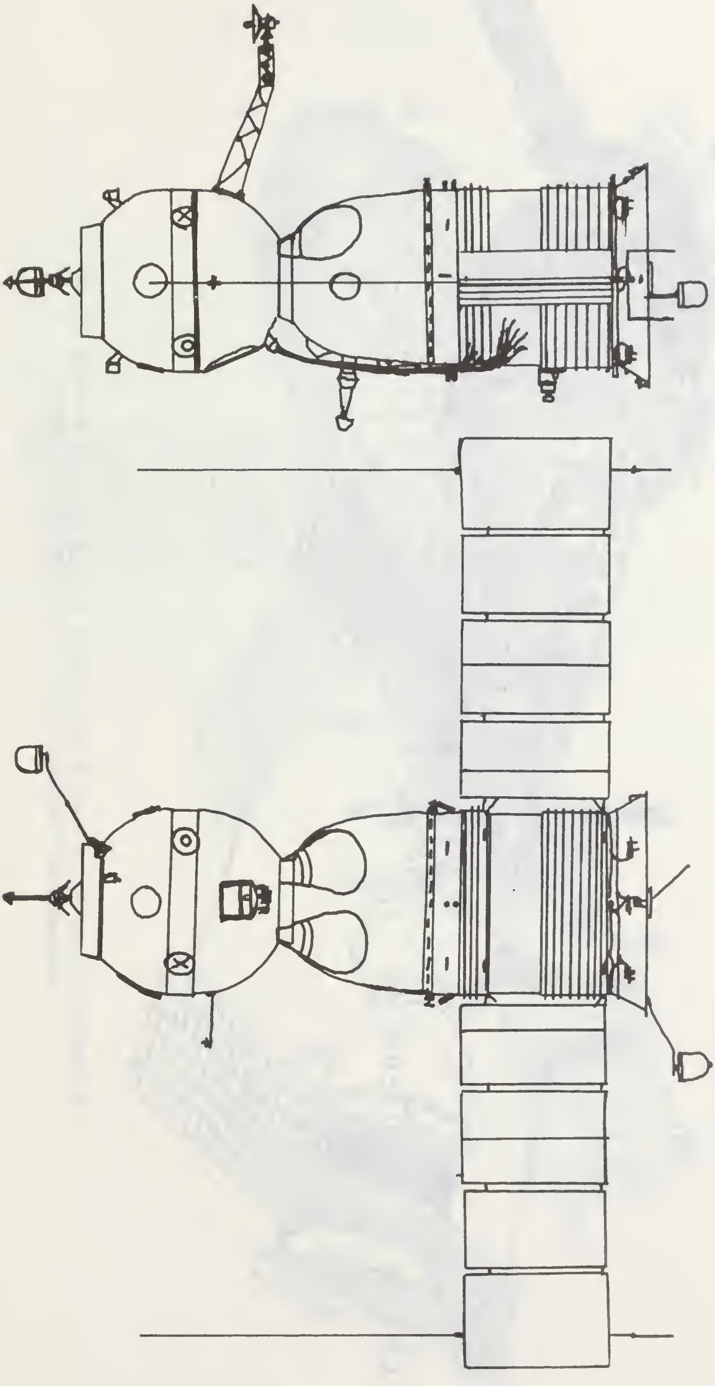

FIGURE 50.—Soyuz 10 or 11, two views, showing the revised docking and transfer hatch, contrasted with those used for Soyuz 4 and 5. (Drawing by C. P. Vick.)

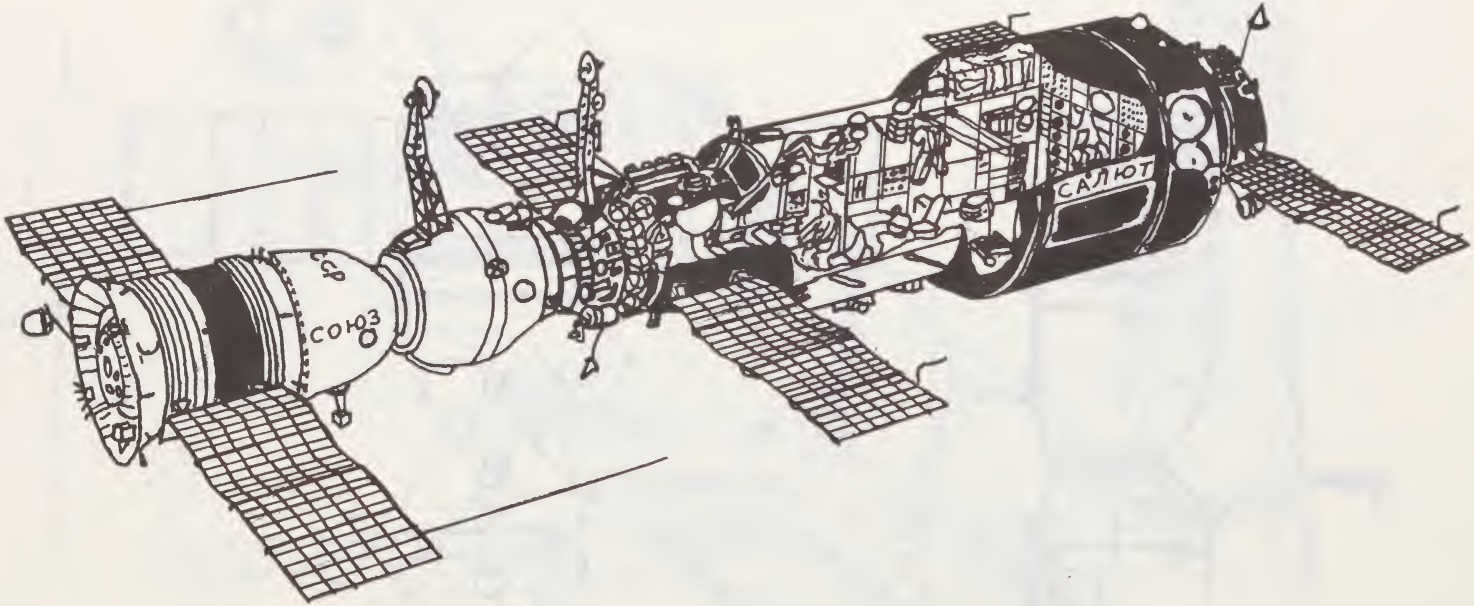

FIGURE 51.—Soyuz 11 as docked with Salyut 1, with cutaway to show interior arrangement of the space station. (Drawing by C. P. Vick.)

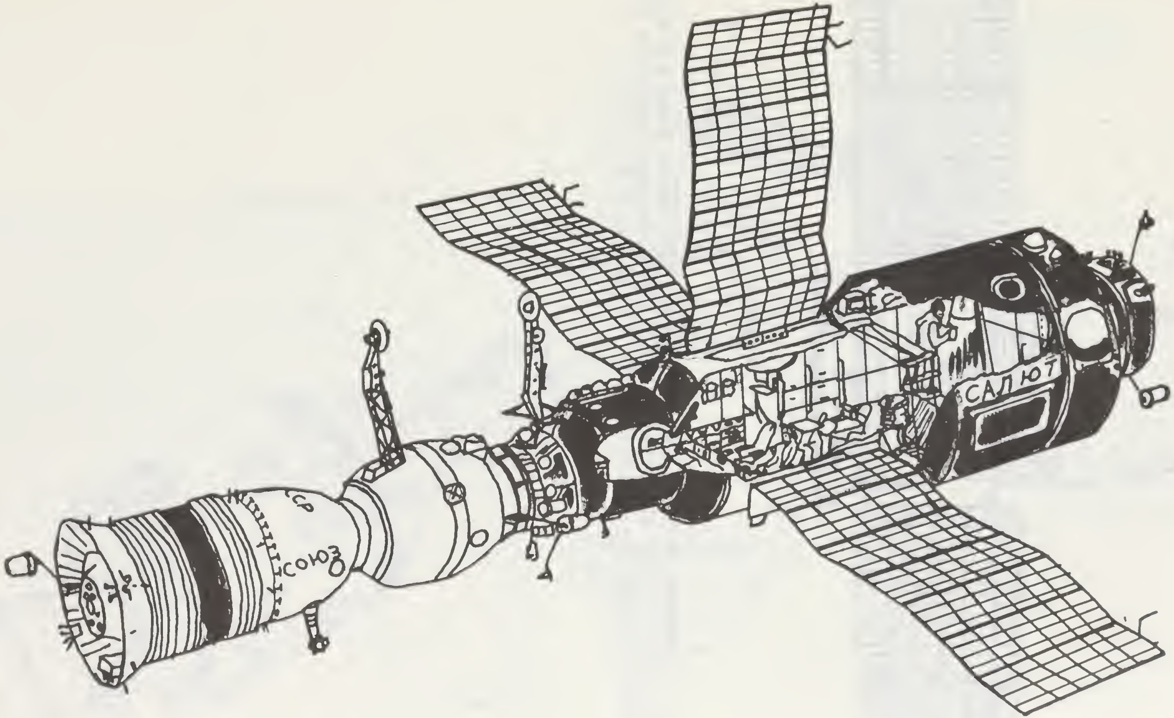

FIGURE 52.—Soyuz 17 as docked with Salyut 4, with cutaway to show the interior arrangement of the space station. Major revisions are the absence of solar panels on the Soyuz ferry craft and the switch to three large, steerable solar panels on the station. (Drawing by C. P. Vick.)

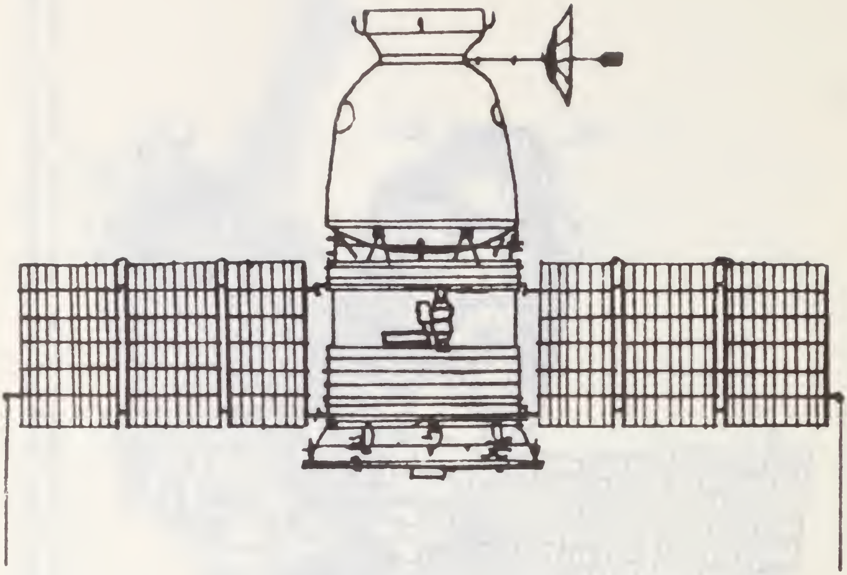

FIGURE 53.—A manned precursor for circumlunar flight in the Zond 4–8 series, essentially like a Soyuz with three solar panels to each side instead of four, and without the orbital work compartment. (Drawing by C. P. Vick.)

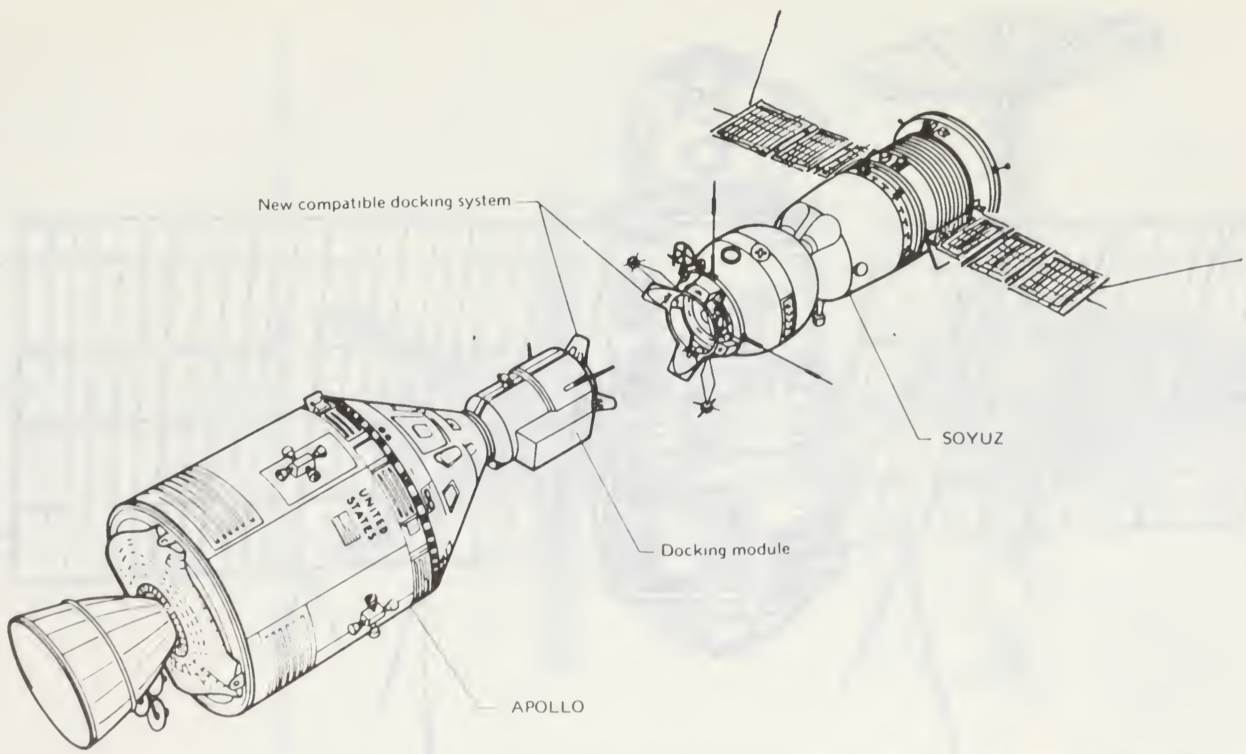

FIGURE 54.—Soyuz 19, most closely resembling a Zond with added orbital work compartment and new androgynous docking gear, being approached by Apollo with the special docking module for the Apollo-Soyuz Test Project.

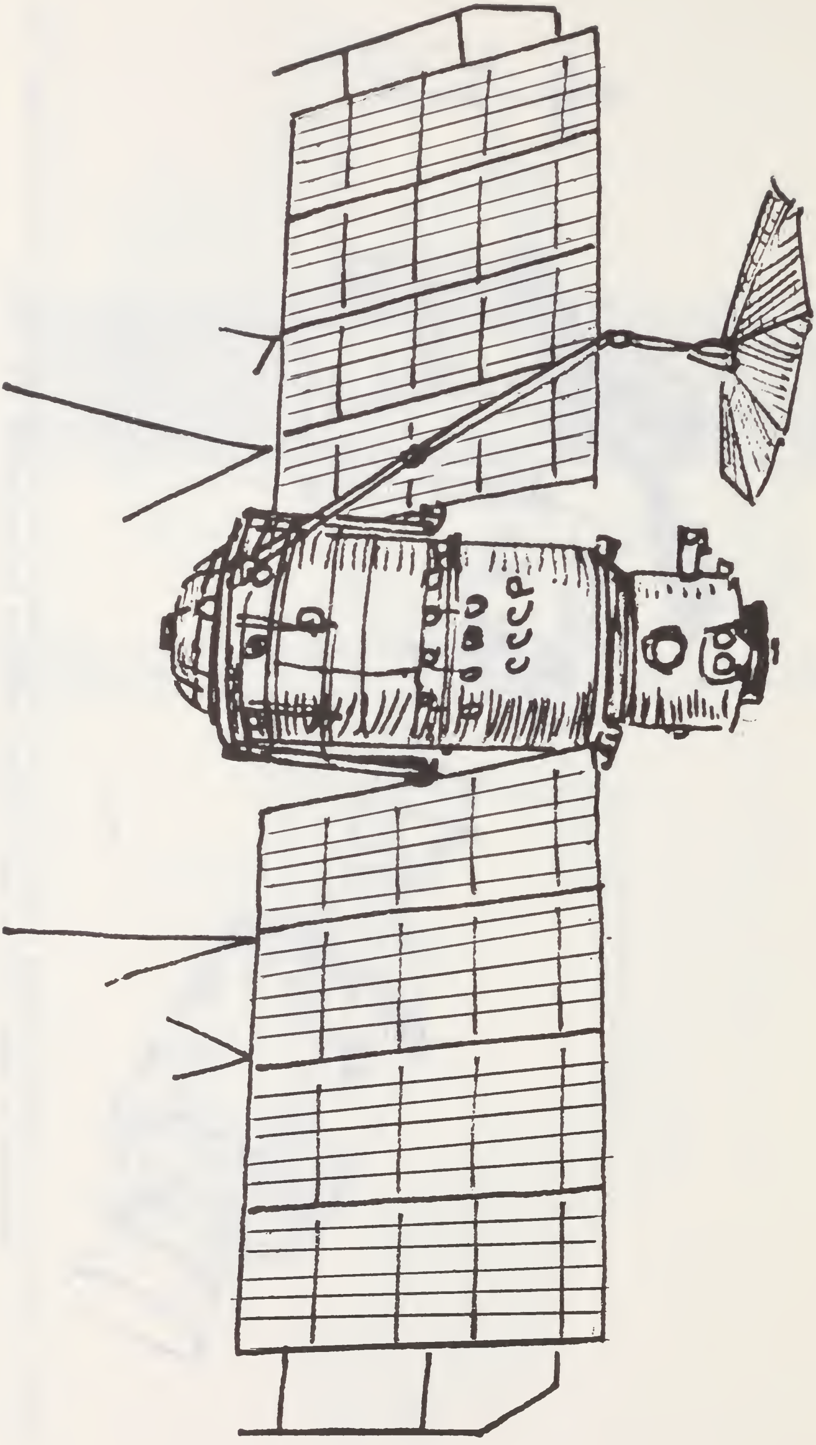

FIGURE 55.—A Meteor weather satellite.

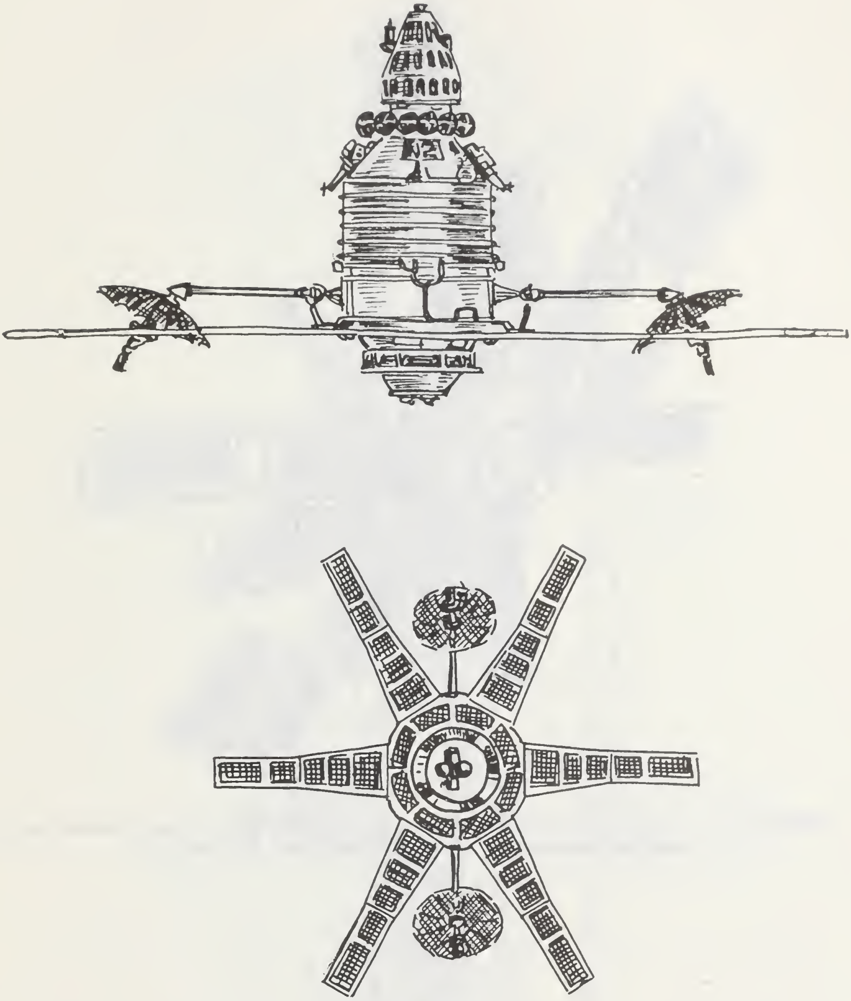

FIGURE 56.—Side and end views of a Molniya 1 communications satellite.

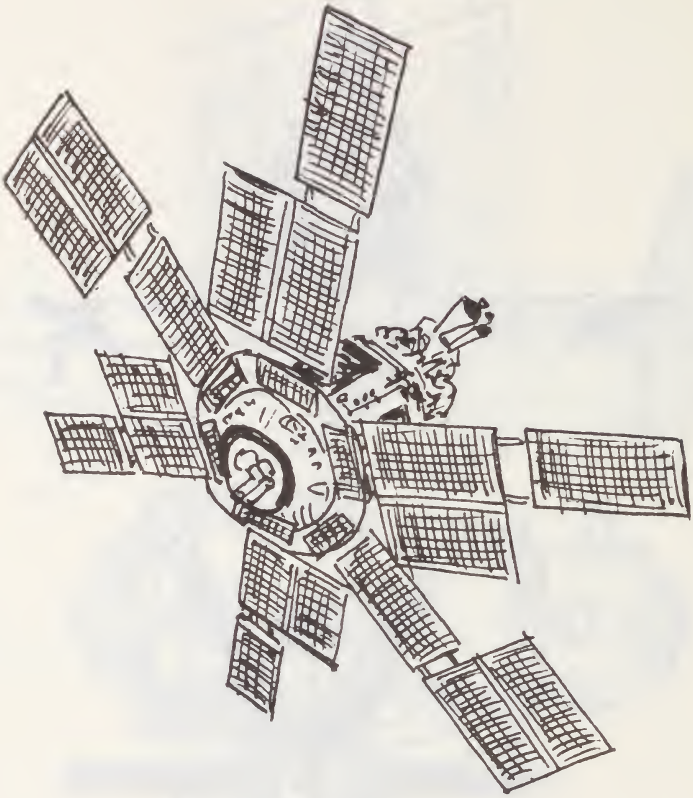

FIGURE 57.—A view of a Molniya 2 showing the addition of more solar panels and replacement of "umbrella antennas" by "horns".

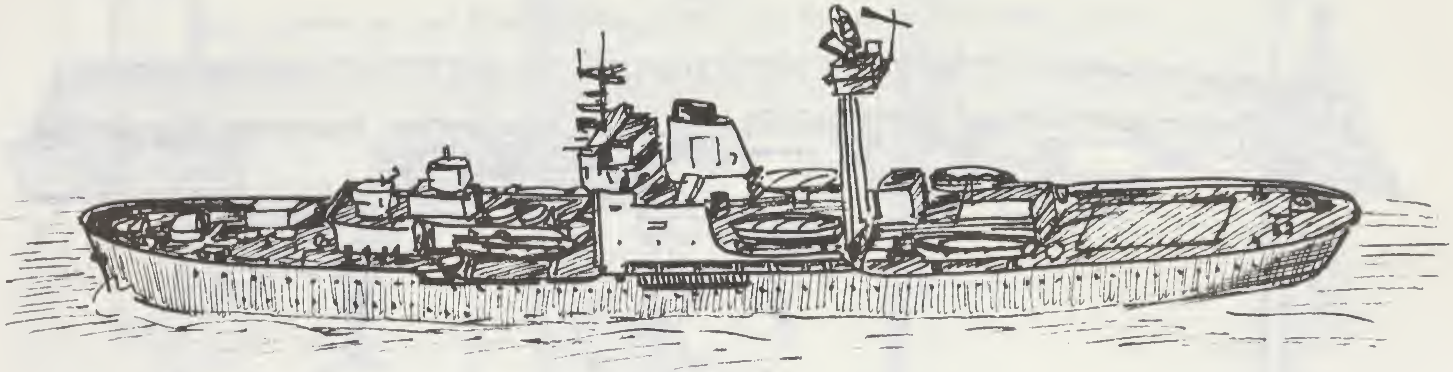

FIGURE 58.—The military missile tracking ship *Chuhotka*, very similar to the *Sutchan*, *Sibir*, and *Sakhalin*.

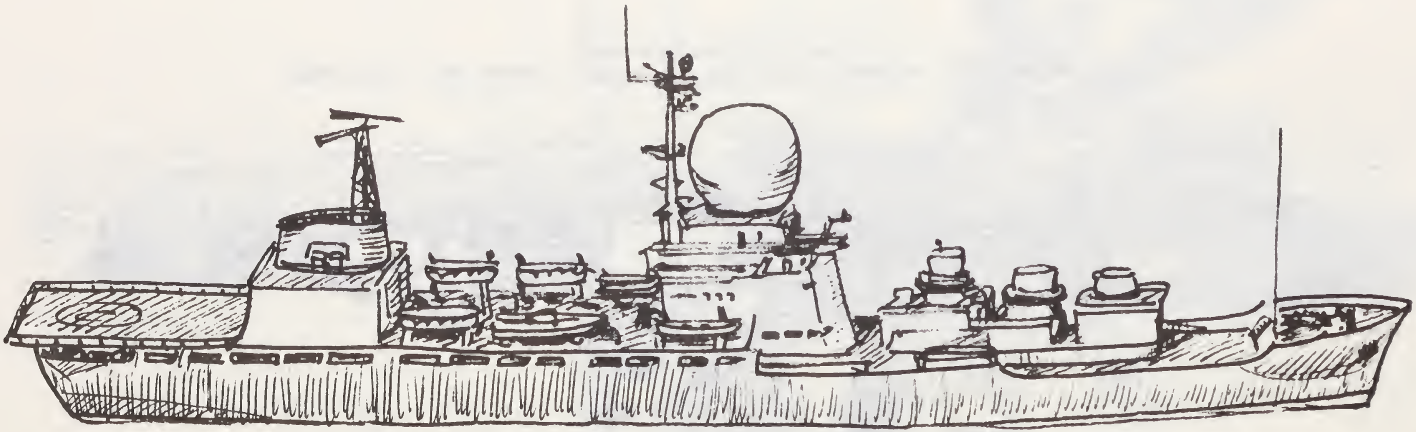

FIGURE 59.—The military missile tracking ship *Chumikan*, very similar to the *Chazma*.

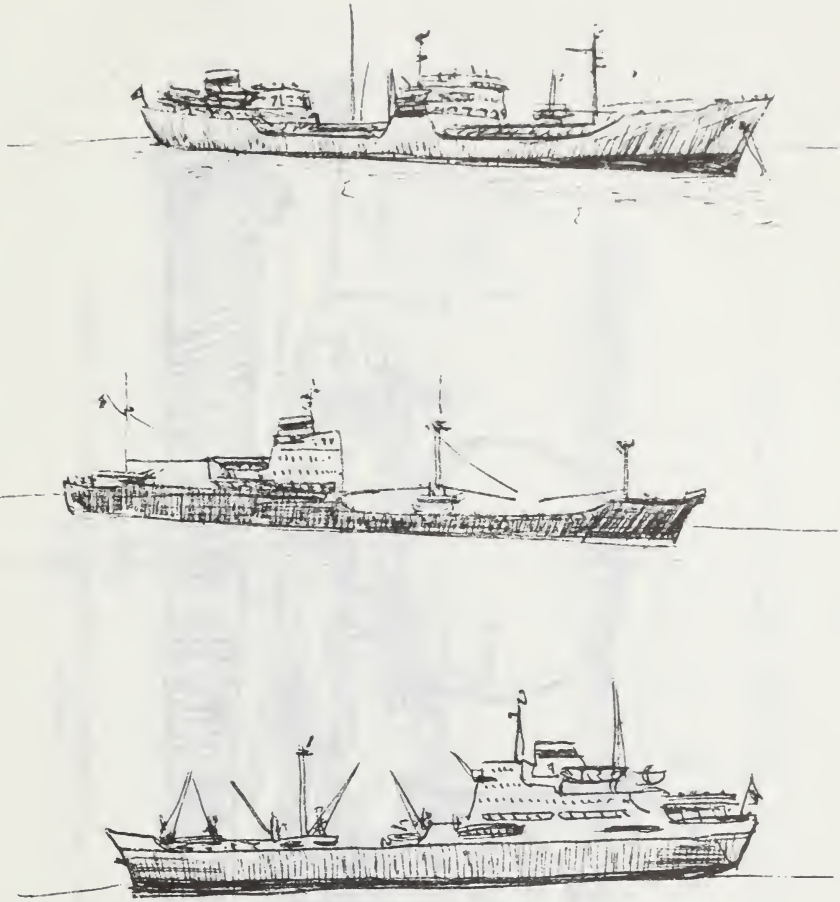

FIGURE 60.—The civilian space support ships *Aksay*, *Ristna*, and *Bezhitsa*.

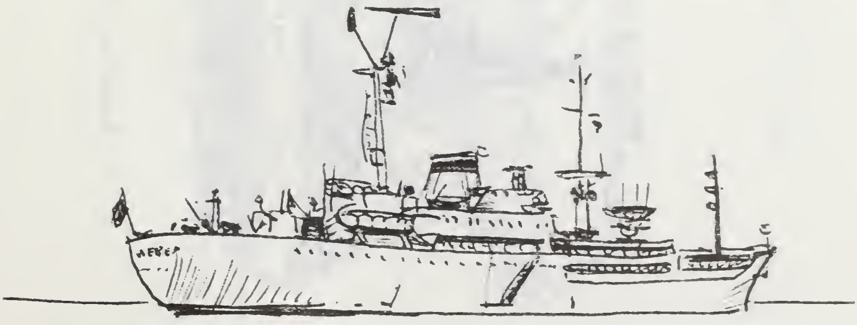

FIGURE 61.—The civilian support ship *Nevel*, very similar to the *Morzhovets*, *Borovichi*, and *Kegostrov*.

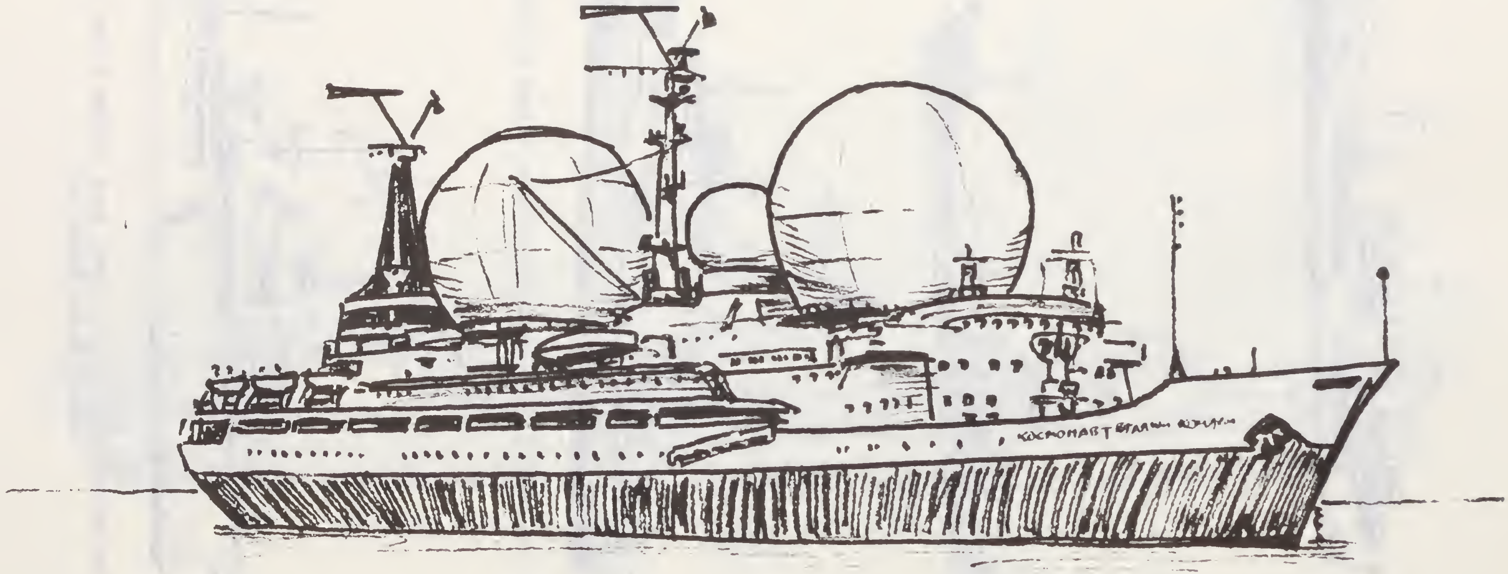

FIGURE 62.—The civilian comprehensive space support ship *Kosmonavt Vladimir Komarov.*

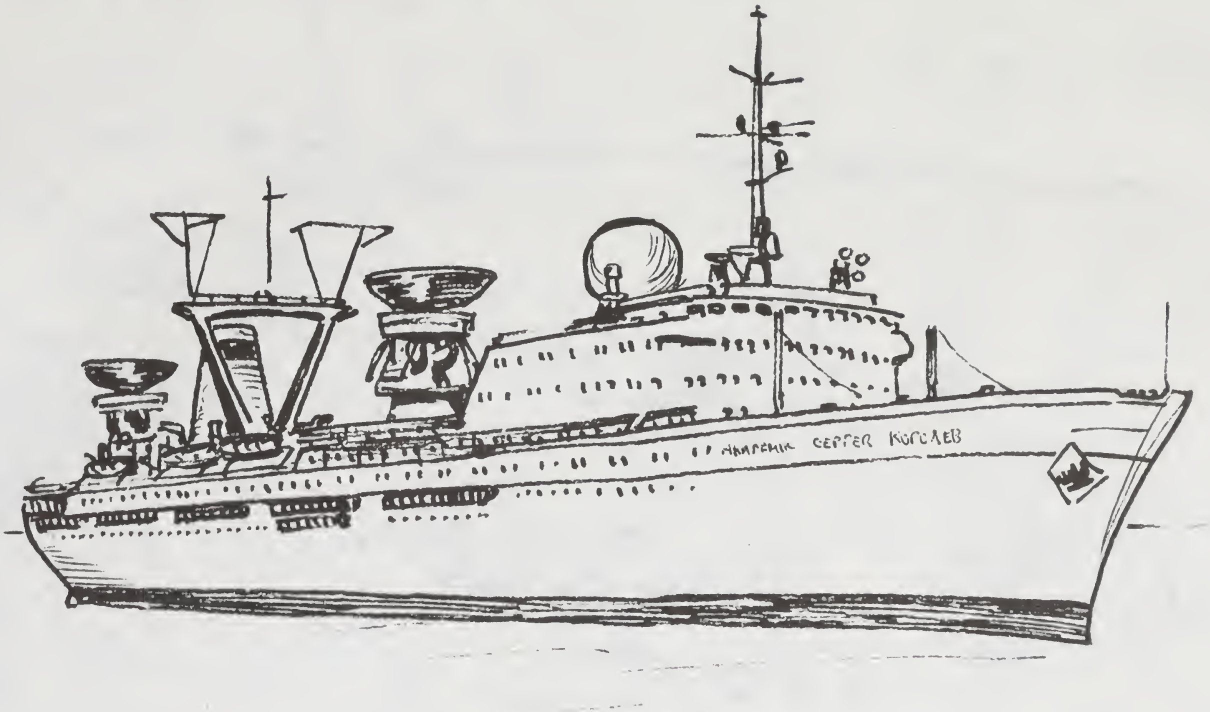

FIGURE 63.—The even larger civilian space support ship *Akademik Sergey Korolev.*

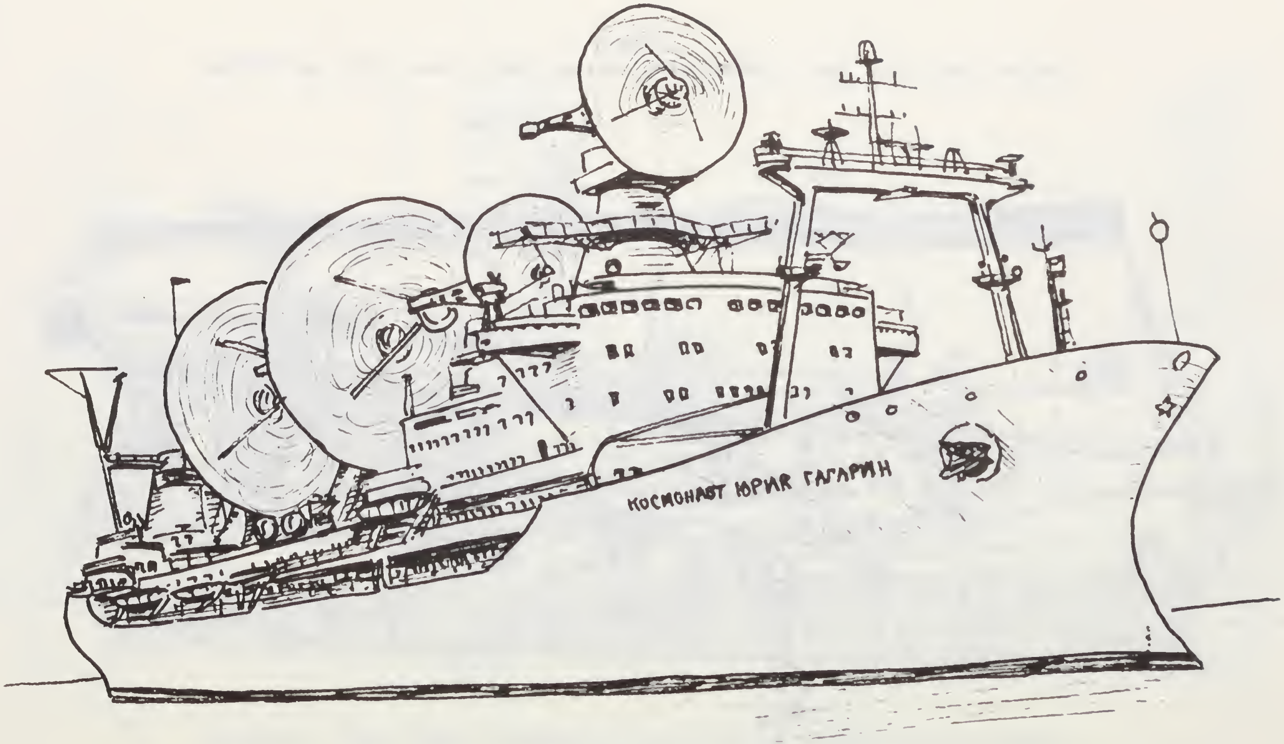

FIGURE 64.—The largest of civilian space support ships, the *Kosmonavt Yuriy Gagarin.*